CA1
MH150
-1983
T76

3 1761 11767136 2

CMHC SCHL
Canada Mortgage and Housing Corporation
Société canadienne d'hypothèques et de logement

Tumbler Ridge Energy-Efficient Subdivision and Community Designs

Research Report

August 1983

Canada

CA1
MH150
-1983
T76

TUMBLER RIDGE

ENERGY-EFFICIENT SUBDIVISION AND COMMUNITY DESIGNS

Final Report

Prepared for
British Columbia Regional Office
Technical Research Division, National Office
Canada Mortgage and Housing Corporation

by

Planning Collaborative Inc.

CMHC Project Managers: G. Hiscox, Vancouver
J. Kiff-Macaluso, Ottawa

This project was funded by Energy, Mines and Resources Canada and Canada Mortgage and Housing Corporation, but the views expressed are the personal views of the authors and no responsibility for them should be attributed to EMR or CMHC.

Digitized by the Internet Archive
in 2023 with funding from
University of Toronto

https://archive.org/details/31761117671362

TABLE OF CONTENTS

Energy-Efficient Community Design at Tumbler Ridge

SUMMARY

This study develops and assesses the costs and benefits of community design principles for energy conservation, applied to the Town of Tumbler Ridge, a new resource community currently being developed in north eastern British Columbia. The study focuses on reducing the capital costs of roads, services, district heating networks, and site development; and on reducing operating costs for residents, businesses, and government, in the form of space heating and transportation costs.

Design principles are developed in four major areas:

- land efficiency: compact lots and housing clusters
- network efficiency: minimizing the lengths of roads and services
- solar access: orientation and spacing of houses to receive passive solar gain
- wind protection: reduction of wind velocities and infiltration-related heat loss.

This is accomplished through design patterns such as:

- compact lots oriented north-south, along east-west and north-south streets
- housing clusters, primarily in the form of culs-de-sac of 20 to 30 units
- retention of major tree shelter belts throughout the community
- compact community form
- radial collector roads from neighbourhoods to the Town Centre
- location of the highest density development (apartments) within walking distance of the Town Centre.

All of the proposed design patterns have economic benefits. With site planning measures to reduce space heating costs, energy savings vary with the construction quality of the house. The 1982 dollar value of measures for a moderately energy efficient house range from

- $25.00 to $45.00 /year for solar access
- $30.00 to $40.00/y for wind protection
- $54.00 to $74.00 / year for the combined effects of solar access and wind protection, or 12 to 17% of the annual heat load.

Site planning measures which affect roads and transportation costs are significant, but the dollar value of savings varies with interest rate assumptions. In comparison with a conventional subdivision, a compact subdivision can save as much as $8,250/unit in capital costs, and $110.00 / year in operating costs, for annual savings of $1,359 to $1,767 / unit (depending on borrowing rates). If a district heating system is installed, a further $2,800 / unit in capital costs (translated into heating bill savings of $430.00 to $572.00 /year when amortized) can also be saved.

At the community layout scale, every km of arterial or collector road which can be removed from the Plan will save nearly $950,000 in capital costs or $151,00 to $189,000 in interest charges and operating costs yearly.

The study concludes that the highest priority in community design should be given to measures to create compact community and subdivision layouts, and to reduce the lengths of roads and services. Site planning measures to reduce space heating loads have relatively less value, but are still desirable if they can be introduced without significant costs (as appears to be the case).

1. PURPOSE OF THE STUDY

Planning Collaborative Inc. was retained by Canada Mortgage and Housing Corporation to undertake a study to develop energy-efficient subdivision and community designs for Tumbler Ridge, a new community being built to service the North East Coal developments in British Columbia.

The objectives of the study were:

1) to promote energy-efficient residential subdivision designs at Tumbler Ridge

2) to assess the potential for energy conservation at Tumbler Ridge through energy-efficient urban design and planning

3) to compare the costs and benefits of a conventional approach to community design with one sensitive to energy efficiency

4) to prepare guidelines for energy-efficient subdivision design and site planning for Tumbler Ridge.

The study was prepared in conjunction with three other studies also commissioned by CMHC and the British Columbia Ministry of Energy, Mines, and Petroleum Resources, to assess the potential for energy conservation at Tumbler Ridge:

- the prospects, costs, and potential for energy-efficient housing (Saskatchewan Research Council)

- the feasibility of a district heating system for the community (Cogeneration Associates)

- financing alternative for energy-efficient housing. (Edwin Reid and Associates).

2. TUMBLER RIDGE

Tumbler Ridge is the site chosen by the British Colmubia Government in 1977 for a new community to service the North East Coal developments. A comprehensive Conceptual Plan was prepared to provide a social, physical, financial, and organizational framework for a community with an ultimate population of 10,500. The initial stages of development to 1990 envisage a population of 6,200.

The Conceptual Plan is oriented towards an open community with social stability, free of the high labour turnover, and company or government dominance which plague other resource towns. The physical component of the Plan is guided by several principles:

- sensitivity to the natural environment
- high quality urban development standards to lend permanence to the community
- a resilient town structure adaptable to change
- concern for energy conservation (addressed in this study).

2.1 Environmental Setting

The Tumbler Ridge townsite is located at 55° 8' North Latitude and 121° 0' West Longitude, some 660 km north of Vancouver and 515 km west of Edmonton. The nearest existing communities are Chetwynd and Dawson Creek, both 88 km to the north. (Figure 1).

The relative isolation of Tumbler Ridge results in construction cost premiums of 15 to 30% more than comparable resource communities, because of the distances over which labour, materials, and fuels must be imported.

The townsite lies east of the Rocky Mountains on the boundary between the Alberta Plateau and Rocky Mountain foothills. It consists of several gravel terraces facing west above the Murray River and Flatbed Creek. Tumbler Ridge, from which the town draws its name, rises 300 m to the east (Figure 2). To the west, the site overlooks the valleys of the Murray River, Wolverine River, and Bullmoose Creek, which drain the foothills and mountains containing the various coal-bearing formations upon which the town will depend. The gravel terraces are bounded by a steep scarp up to 80 m high, separating them from the floodplains of the Murray River and Flatbed Creek.

Although the townsite has a commanding setting, the buildable land area is limited, necessitating a compact community form, so as not to waste this resource and allow some flexibility for future development. Also,

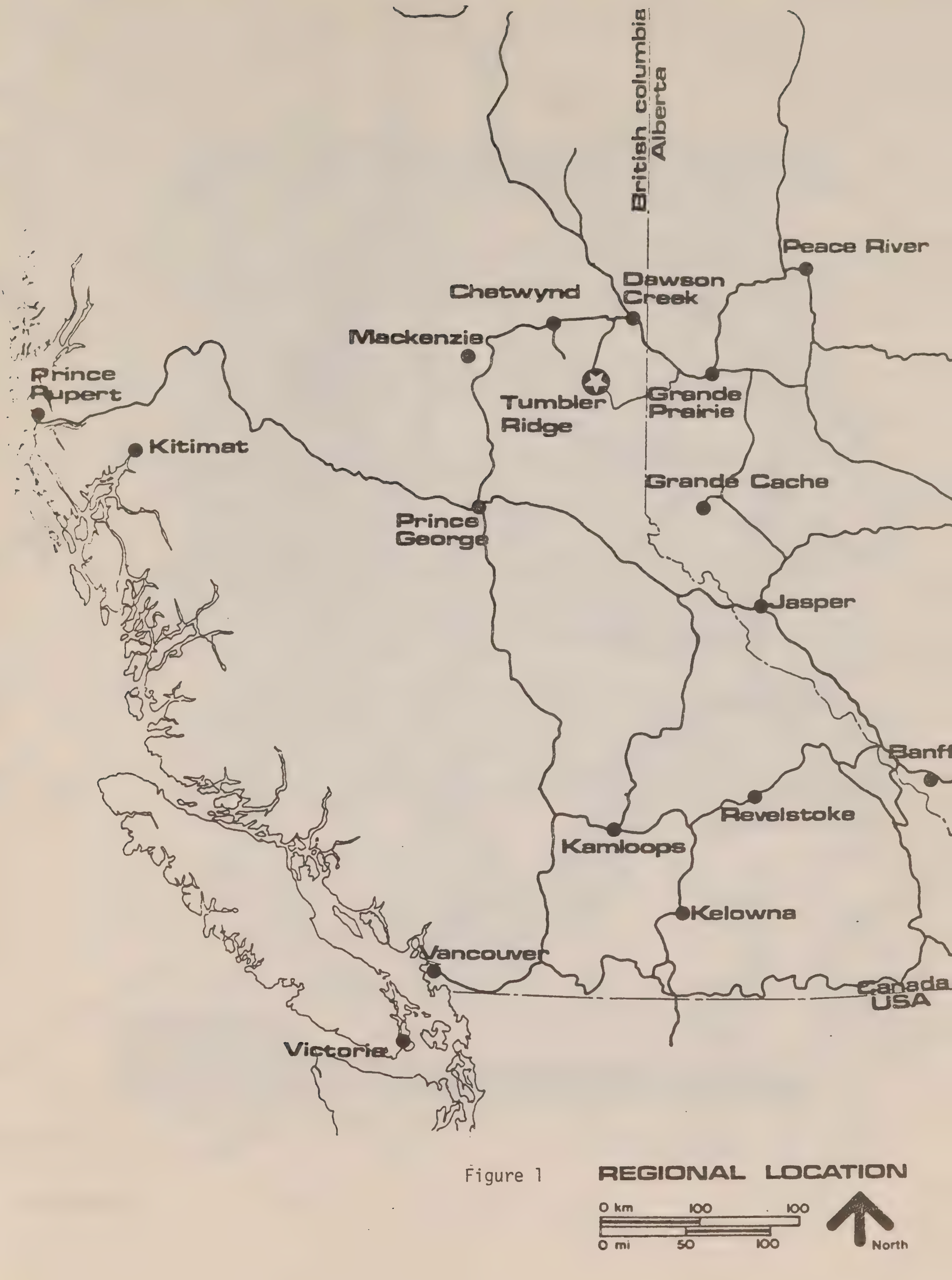


Figure 1 REGIONAL LOCATION

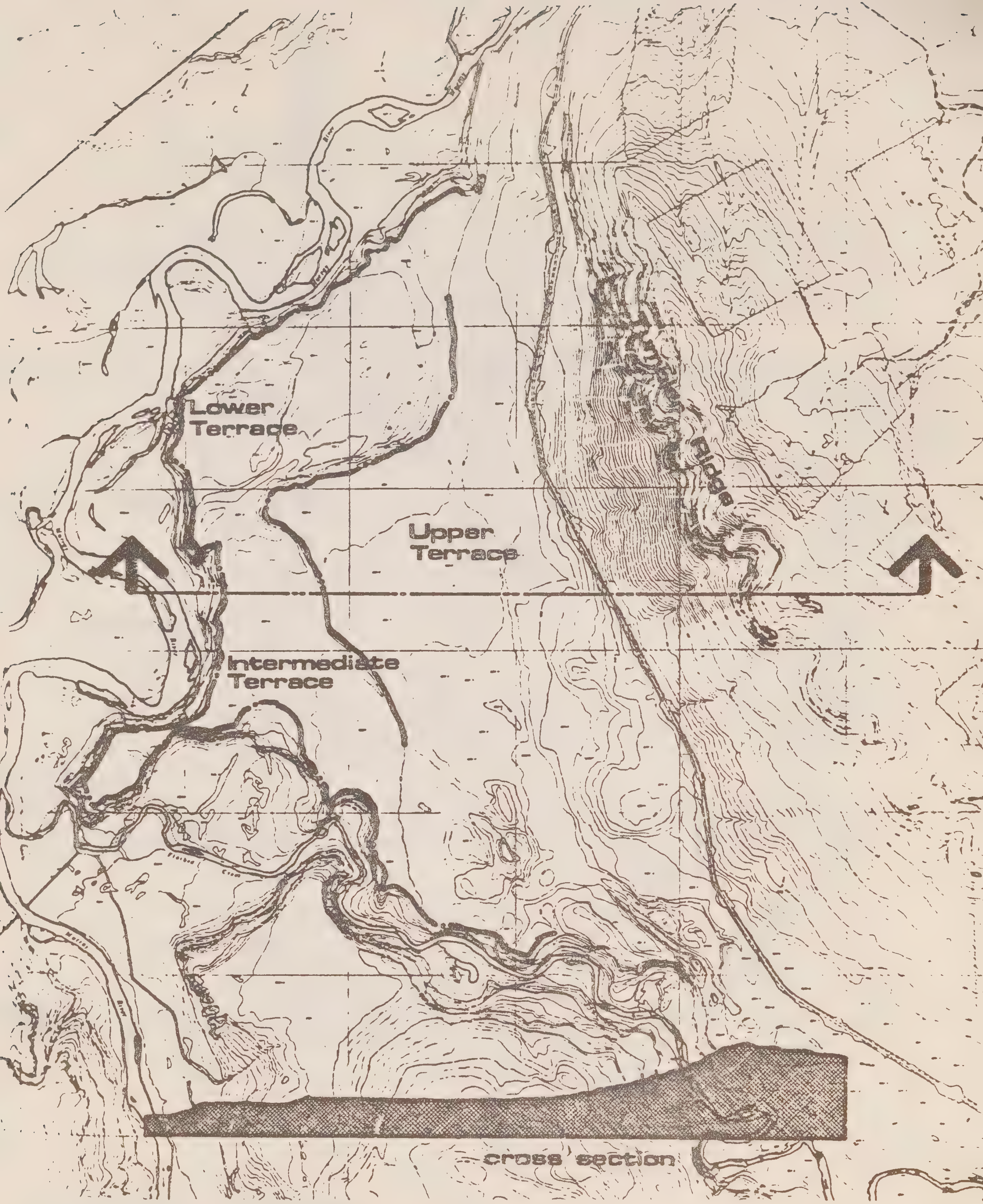


Figure 2

RELIEF

the site is constrained on all sides, putting definite limits on the physical extent of the town. Thus, land efficiency was a major concern in the study, not only for energy conservation purposes, but also because the townsite simply has no room for "sprawl".

Tumbler Ridge is affected by two main climatic influences: continental weather systems with outbursts of cold arctic air masses. coupled with the periodic intrusion of Pacific frontal systems. This provided the region with long cold winters and warm summers with moderate precipitation.

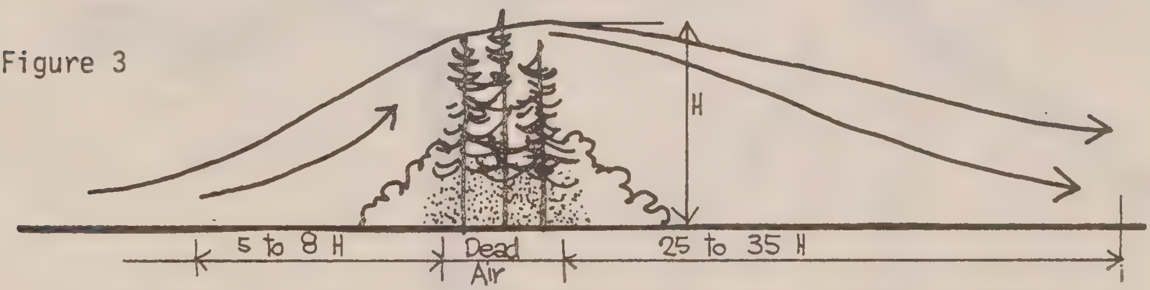
The coldest period of the year is from mid-January to mid-February. Average temperatures are -20 to -18^{o}C, and range as low as -45 to -40^{o}C. Average temperatures in summer are 10 to 16^{o}C, with hot periods as high as 29 to 32^{o}C.

The heating degree days* for the year are 6,152 (Celsius), or 4,838 for the heating season from November to April. These values are typical of the cold middle latitude of Canada, for which a concern with energy conservation in housing construction is increasingly important.

Wind is a constant factor on the townsite year-round, coming from the south and south west at average speeds of 18 km/h. Since infiltration is a major component of heat loss in conventional house construction, some form of wind protection or reduction is important in the Community Plan, where it can be provided more cheaply than internal measures to isolate each house from its effects.

Protection from wind requires the saving of trees. These will be most critical at the outer edges of each terrace, where trees are most windfirm. Dense windbreaks of conifers (which make up much of the Tumbler Ridge vegetation, along with poplar and cottonwood) protect an area in front and behind (Figure 3). To maintain a reasonably protected townsite, recurring windbreaks at distances of 30 to 40 times tree height are necessary (Figure 4).

Figure 3



* The total annual degree days is the sum of the difference between 18^{o}C and the mean temperature in ^{o}C of every day in the year when the mean temperature is below 18^{o}C.

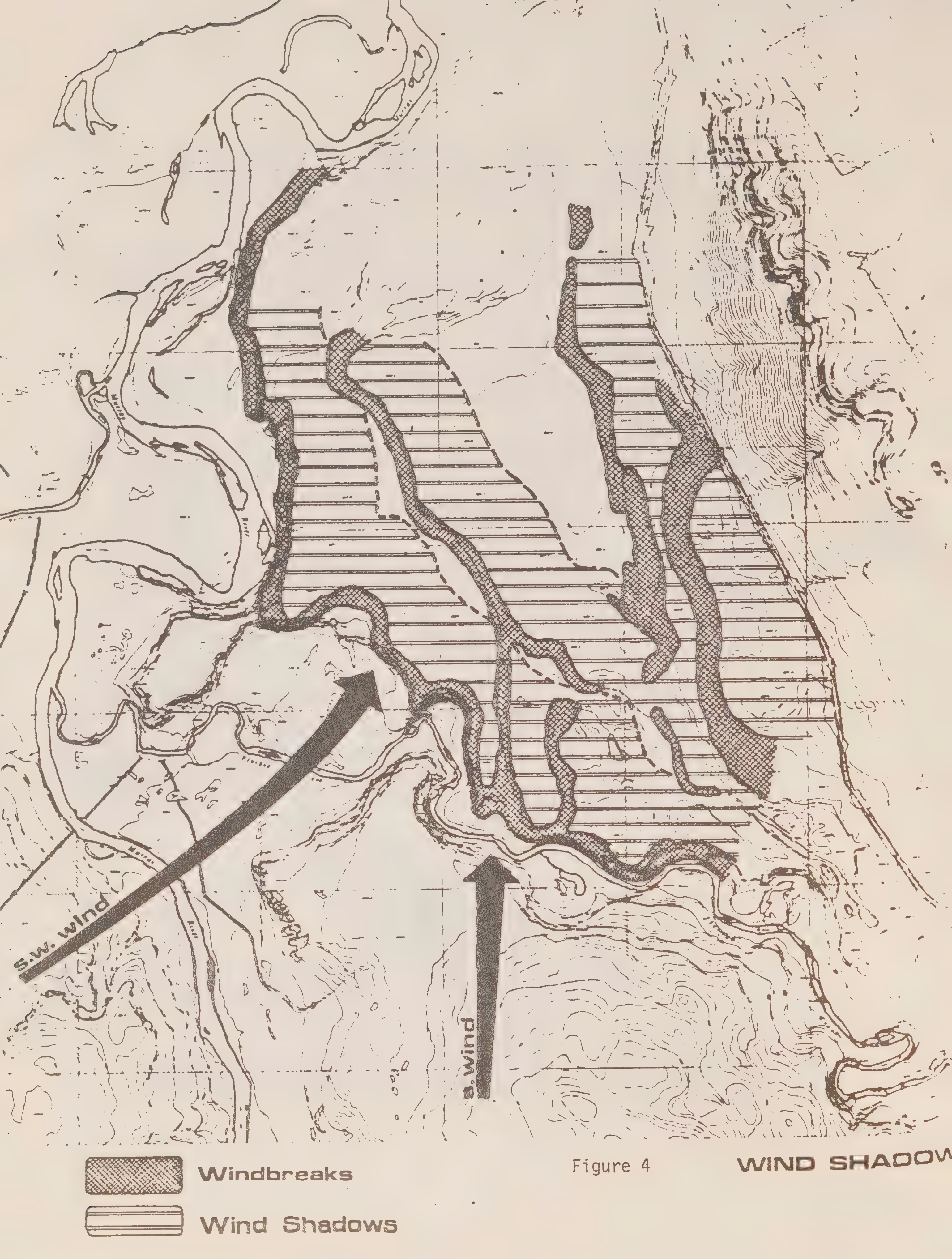


Figure 4 WIND SHADOW

At high latitudes such as Tumbler Ridge, winter sun angles are very low, casting long shadows. For example, at noon on December 21st, the sun's altitude is only 11° 33', barely above the 10° altitude felt to constitute "useful" solar radiation for passive solar heating purposes. However, the sun's altitude rises rapidly with each succeeding month, so that useful passive solar radiation can be expected after mid January or before late November. There is some potential for passive solar design at Tumbler Ridge, if it is recognized that its usefulness is primarily in the fall and spring.

3. ENERGY-EFFICIENT COMMUNITY DESIGN

A major objective of making Tumbler Ridge an energy-efficient community is to reduce its vulnerability to rising energy costs, uncertain supply, and the disadvantages of a remote location. Community design can contribute to this objective, but is only one aspect of a complex picture. Buildings, houses, roads, and neighbourhoods are frameworks for human activities and movement, and therefore, for the consumption or conservation of resources. It is equally important how residents, businesses and governments make use of this framework. In other words, users and their demands are an integral part of energy consumption patterns. These are best addressed through strategies which affect motivations, lifestyles, or energy prices.

An undertaking as complex as a new community consumes prodigious amounts of resources: land, labour, capital, materials, and energy. On the supply side, energy conservation is in turn, one aspect of a broader concern with effective use of resources, not only in terms of those used to build the community (which must be paid for many years after), but also in terms of the resources used to operate it. These factors are interrelated: as an example, the delivered cost of energy to the consumer, be it electricity, natural gas, or district heating hot water, is a complex amalgam of administration and labour costs, the capital costs of local and wider delivery networks, financing charges, etc., and often only a small percentage for the actual fuel consumed. Costs to the consumer can be reduced by affecting any one or several of these factors.

While the approach taken in this study has been to focus on the community "framework" and principles which would result in less energy use under normal operating conditions; at the same time, it is oriented to achieving useful capital and operating cost savings in other areas affected by community design, so as to make Tumbler Ridge more cost-efficient in all of its aspects.

3.1 Capital Costs

Site development and services, roads, and other utilities are major front-end costs for any community. These costs are made up largely of materials and labour, with a relatively small component for energy (fuel) costs. Energy costs can be reduced by minimizing earth-moving and site preparation, and using low energy input building materials and assemblies.

Capital costs are incurred at one time only, and therefore, the savings realized will not accumulate over a period of years as with operating costs. However, they are paid for over the life of the community. Other reports have identified housing affordability as a major consideration in the development of Tumbler Ridge and the attraction of a skilled work force to the community. Efforts to reduce community development capital costs will have significant effects on housing prices, or alternatively, allow more money to be put into energy conservation measures within the house. The effects of such reductions are further magnified at Tumbler Ridge, given current high interest rates (which drive up the costs of amortizing capital improvements) and the cost premiums associated with a remote site.

A related study in this series is examining the feasibility of a district heating hot water system for the community. For this particular energy source, reductions in the capital costs of the local distribution network will have a major effect on the costs of delivered energy to consumers.

Capital cost reductions are addressed in the design principles through two aspects:

- land efficiency: compact lots (in terms of frontage and depth) consistent with each housing type, and efficient arrangements and clustering of lots
- Network (roads and services) efficiency: lotting arrangements to minimize road widths and lengths, and servicing runs.

3.2 Operating Costs

These can be distinguished for three major groups:

- residents: major energy costs are in space heating for housing and transportation. Residents are numerically the largest group in a community, and make by far the largest number of trips.

- Businesses and services: major energy costs are also in space heating and transportation. Processing or manufacturing costs will not be a factor, since the businesses which have major energy expenditures in this area, will make them irrespective of location or community design. The energy use of nearby mines and processing equipment will undoubtedly be far higher than the total energy expenditure of the community.

  Only those businesses making deliveries or service calls are likely to be affected by community design. Some services such as mail delivery have found means to supply the service (for example, drop boxes) without having to make deliveries within the neighbourhood. These would be affected by the location of the neighbourhood, but not its layout. Such options may not be available to many businesses.

- Municipal services: these include "hard" services such as sewers, water, and other utilities, for which the variable operating and maintenance costs are relatively small, and "soft" services which make use of, or repair local roads. There are opportunities for energy conservation in this area. A number of services must use every road in the neighbourhood: emergencies (fire, police, ambulance), school bussing, public works (snow removal, garbage collection, etc.). Minimizing the lengths of roads to be travelled by such services not only saves on fuel costs, but may also save on the labour required to drive vehicles.

3.21 Space Heating

Preliminary indications are that community design will have a useful but limited effect on energy use for housing space heating purposes. The monetary value of this energy is dependent on the costs of heat delivered by the various alternative sources (ranging from \$6.25/GJ* for district heating to \$10.21/GJ for electrical heating, in 1982). Therefore, the cheaper the heating source, the less value any specific energy conservation measures will have for the individual consumer.

If energy conservation for space heating were an overriding concern in community design, then the housing mix would be biased towards attached forms of housing (such as townhouses and apartments) since these are inherently more conserving than detached housing forms. Attached housing forms at higher densities than detached, also result

---

* GJ = Giga Joule, a measure of energy.
1 GJ = 1 billion joules
= 9,478 BTU (British Thermal Units)
= 277.7 kWh

in greater land efficiency.

However, housing mix is also based on marketing and considerations other than energy conservation, which have not been addressed here. Therefore, the original housing mix projections, with high percentages of single family detached units, have not been altered. (Figure 5)

Site planning can reduce space heating costs in two ways:

1) Solar Access: although limited in winter, passive solar gain can reduce heating needs. This is achieved by orienting the main living spaces and most of the windows of the unit towards the south.

2) Wind Protection: Since planting close to the unit is unlikely to reduce wind speeds or infiltration, wind protection must be addressed at the community design scale by retaining major windbreak tree belts.

3.22 Transportation Costs

Transportation costs can be modified in several ways:

- reducing the number of trips (that is, the propensity to travel)

- encouraging energy-efficient modes of travel over others (for example, pedestrian trips above all, transit (particularly for the journey to work) second, private cars last.)

- reducing average trip length.

It is unlikely that community design would affect a human activity as basic as the propensity to travel. Certain journeys are essential: to work, to school, to shop; and discretionary trips (to recreation, etc.) are a small percentage of the total.

However, it can have some influence on the mode of travel and therefore, the total number of vehicular trips. To the extent that these journeys can be shifted to modes other than the automobile (bicycles, walking, transit), then energy conservation will be improved.

The community road layout can also aid in making trips as short as possible. This is achieved through the principles of land efficiency and network efficiency already mentioned under capital costs. The key to significant savings in transportation costs is the accumulation of small savings in trip length over large numbers of trips taken within the community over a year.

However, all of these accumulated small savings can be offset if development is permitted outside the town boundaries (for example in the form of rural estate lots). Cost to service small numbers of remote households with school bussing, snow plowing, fire protection, etc., not to mention increased trip lengths for such households, will quickly

Figure 5

TUMBLER RIDGE
1991 HOUSING SCHEDULE

Type	Area	Number	Totals
Detached	Large (111 m^2)	511	
	Small (88 m^2)	510	1,021
Attached	Large (2 x 97 m^2)	68	
	Small (2 x 76 m^2)	67	135
Townhouses	(59 m^2)	112	112
Apartments	(38 m^2)	738	738
Manufactured Homes	(91 m^2)	388	388
	TOTAL UNITS		2,394

Source: District of Tumbler Ridge
Vancouver Office
October, 1981

outstrip any savings which can be built up within the community per se, by making it more compact with an efficient road layout.

Transportation energy savings are not necessarily the same as cost savings. While public transit is probably more energy efficient per passenger km than private cars, in small communities, with low ridership and high labour costs, transit operates at a deficit. The more service provided, the higher this deficit will get.

With a small number of major work destinations, which operate on a shift basis with large turnovers at specified times, Tumbler Ridge is ideal for a mine transit system which would reduce the number of vehicles on the road, together with overall fuel consumption. There would also be the added side benefits of reduced accidents and work absenteeism.

In other aspects of energy conservation, community design has a more limited role. For example, it cannot compensate for the remote location of the community, and the fact that many goods and foodstuffs will have to be imported over long distances.

Community design will have varying effects on the kinds of fuels used for space heating: a limited effect on fuels imported from long distances (electricity, natural gas, oil, etc.), and major effect if district heating, with local fuels or coal, is used.

Space heating is affected by climatic and environmental conditions particular to Tumbler Ridge. The benefits of solar access and wind protection may be valued differently in other communities, especially if they have less severe conditions. Measures to reduce transportation costs are "universal" and equally applicable to communities across the country.

4. DESIGN PRINCIPLES AND PATTERNS

In community design, energy conservation and cost effectiveness translate into several main principles:

- Land efficiency: compact lots and housing clusters
- Network efficiency: reduced roads and service runs
- Solar Access
- Wind Protection

Principles are realized at several levels of detail. For example, wind protection is best realized at the community layout scale because trees must be retained in large groups to have a measurable effect in reducing wind speed. Land efficiency, on the other hand, begins at the scale of the individual house on a lot.

Principles are also interrelated. For example, the house on a lot:

- must be correctly oriented and located for solar access
- should have a certain depth so as not to cast shadows which would shade solar access to adjacent lots
- should minimize frontage and depth for land efficiency.

Therefore, principles must be combined or integrated as design patterns. These are developed at three scales or levels of detail:

- house/lot relationships
- housing clusters
- community layout.

Patterns are also recombined into larger patterns, to develop a detailed community plan. They are further analysed in the following chapter to determine their relative contribution to energy conservation and cost effectiveness at Tumbler Ridge.

4.1 House/Lot Relationships

Principles

- Land Efficiency

  - Minimize lot frontage (composed of the unit width + the applicable number of side yards)

  - Minimize lot depth (usually 30 m), to accommodate a front yard of at least 6 m, the building depth, and a rear yard of at least 6 m (if not used for the Outdoor Living Area), or 7.5 m if used for the Outdoor Living Area.

- Solar Orientation

  This usually requires the long side of the unit facing south, with the adjacent Outdoor Living Area also facing south, where applicable. A north-south lot orientation usually results from this requirement.

These principles are developed in a set of design patterns at a scale of 1:500, for three detached housing types:

- 1 storey bungalow, large (111 m^2) and small (88 m^2)
- 1½ storey split level house, 111 m^2
- 2 storey house, 120 m^2

and two attached housing types:

- 1 storey semi-detached, large (195 m^2) and small (153 m^2)
- 3 storey walk-up apartments.

The patterns generally place each unit on its lot with minimum setbacks, and indicate the shadow patterns cast on November 21st, or January 21st, at 10:00 AM, 12:00 noon, and 2:00 PM, the "window" for useful solar radiation at this latitude.

One of the most important considerations in reducing lot width is the placement of the unit parking space and/or garage. If the parking space can be located in front of the unit, then the lot width can be reduced to the unit facing width + 2 m (made up of a 1 m side yard on either side of the unit). If some side windows are required (for example, bathrooms), then a 1.2 m side yard will be necessary, resulting in a lot width of unit width + 2.5 m.

A driveway to the side of the unit will increase lot widths significantly, but will allow two or more vehicles to be parked on the lot at one time. With two side yards, lot width would increase to unit width + 4m; with one zero lot line and 1 side yard, this could be reduced to unit width + 3m.

The provision of side yard or front yard parking is a matter of policy, but as will be seen, also a matter of municipal costs. Strategies to reduce lot width (zero lot line, front yard parking), can be useful in reducing servicing costs, and have been employed here. In many of the housing clusters illustrated, parking for several vehicles is possible in lots entered from the side, without increasing lot width. A substantial number of such lots within a clustering of lots should accommodate the needs of households with more than one car, while maintaining smaller lot widths.

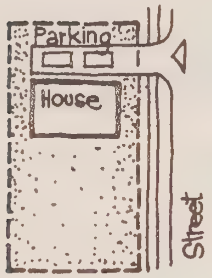


Figure 6: Side Lot Entry

Figures

(7) 1 Storey Detached, 111 m^2

Minimum lot size: 15 x 30 m. If the long axis of a bungalow faces the street, then the full lot width of 15 m will be required. If the short side of the house can face the street, a narrower lot width of 12 to 12.5 m will be feasible. A garage or car parked in front of a house on the north side of the street will block solar access to the south wall to some extent.

The bungalow is a common house form, easily marketed. It casts the shortest shadow of any house type. However, it also has the greatest amount of exposed wall and roof area relative to floor area of the detached house types.

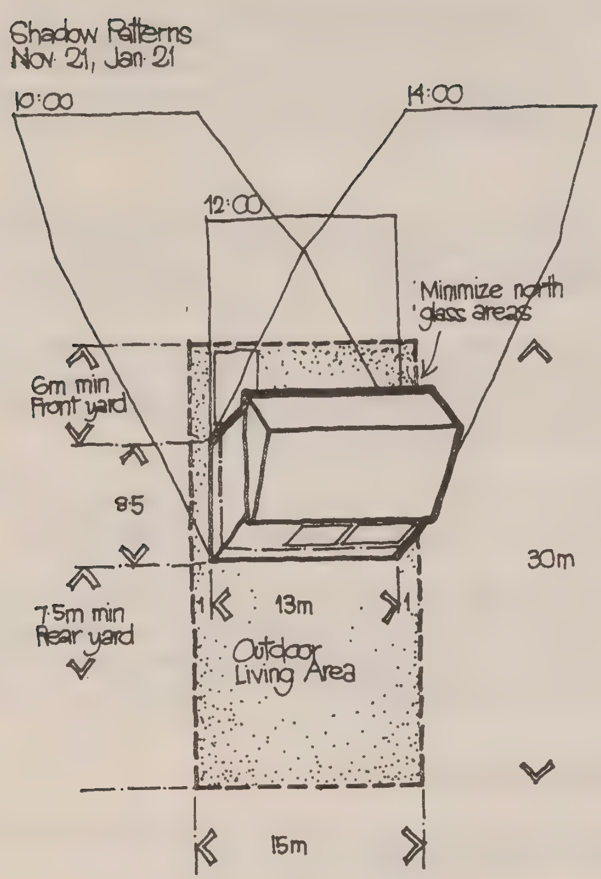
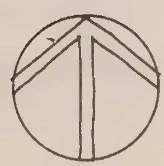


Figure 7

1 STOREY DETACHED 111 m²

HOUSE/LOT RELATIONSHIPS

TUMBLER RIDGE



1:500

(8) 1 Storey Detached, 88 m^2

Minimum lot size: 15 x 30 m. Although this housing type is probably shorter than the larger unit, the difference may not be enough to result in a change in lot width.

(9) Split Level Detached, 111 m^2
(10)
Minimum lot size: 12.5 x 30 m. 15 x 30 m lot size is also acceptable. This is an ideal house form in many respects: a 2 storey + partial (½) basement portion is oriented towards the south (i.e., 2/3 of the living area of the house), with a 1 storey + full basement portion towards the north (i.3. 1/3 of the living area of the house).

This house type casts approximately the same shadow as a 1 storey bungalow, if correctly oriented. However, it is shorter than the bungalow for the same floor area above grade.

The large south wall is adaptable to a variety of window placements to optimize passive solar design. A garage or parking space to the south of the unit also does not affect solar access, since such a large wall area can be provided.

The low roof portion of this housing type can be extended to provide a car port or enclosed garage as required.

The split level is a relatively common housing type in many Canadian suburbs, but is less prevalent in resource communities. As a housing type, it has the added advantage of being able to be integrated with a streetscape of 1 storey or 2 storey units.

(11) 2 Storey Detached, 120 m^2

Minimum lot size: 9 - 10 m x 30 m; the most land-efficient of the detached housing types.

This house type is also the most energy-efficient of the detached housing forms (i.e., less exposed area relative to floor area). However, it is not a characteristic house type in many resource communities. It also casts long shadows at high latitudes, possibly blocking sunlight to other units unless appropriately located (for example, to the south of park areas and windbreaks, or to the south side of east-west streets).

(12) 1 Storey Semi-Detached, 195 m^2

Minimum lot size: 2 x 10m x 30 m. A slightly longer street frontage, 2 x 12.5 m, allows side yard parking.

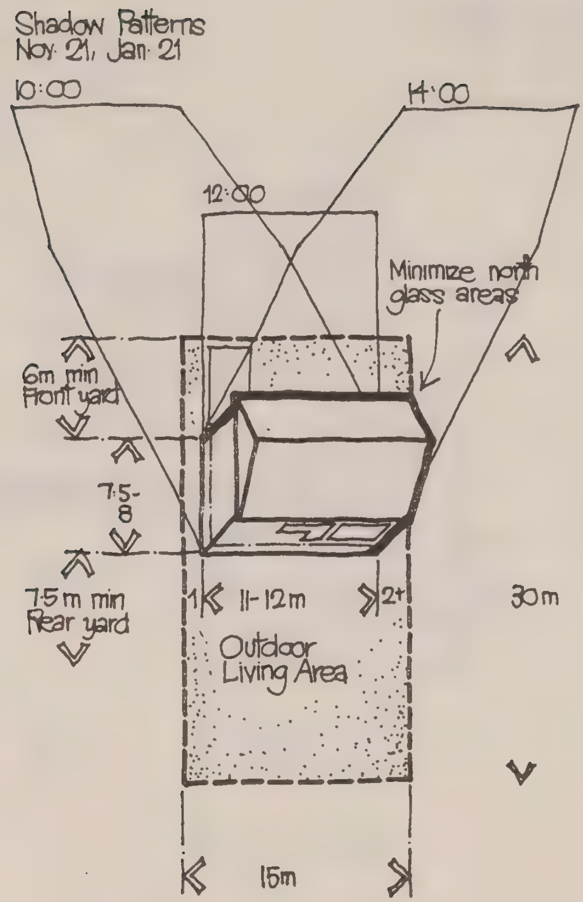


Figure 8

1 STOREY DETACHED 88 m^2

HOUSE/LOT RELATIONSHIPS

TUMBLER RIDGE

1:500

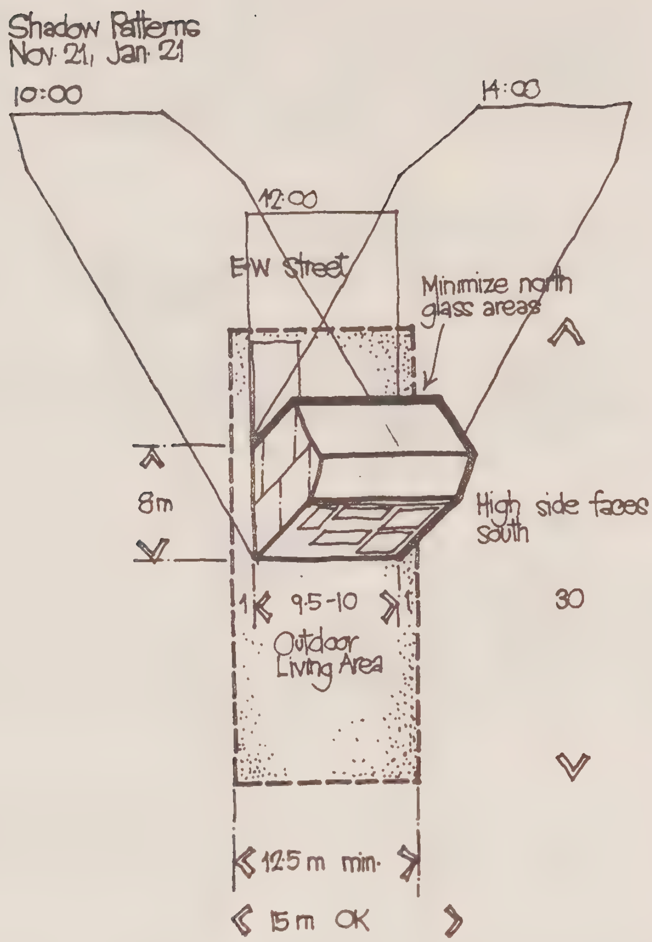


Figure 9

1½ STOREY DETACHED 111m² (3 LEVELS) HOUSE/LOT RELATIONSHIPS

TUMBLER RIDGE

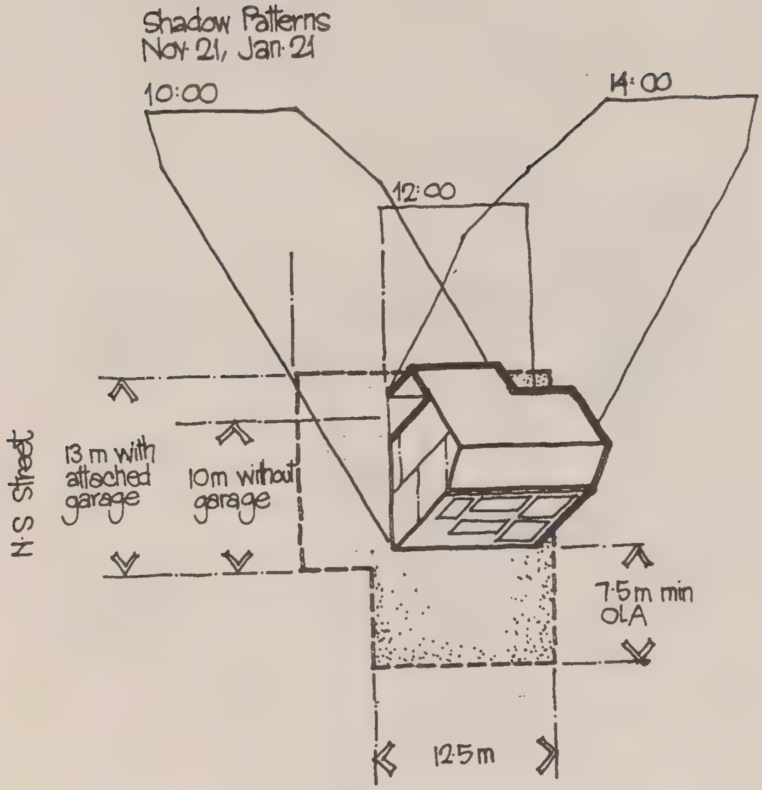


Figure 10

HOUSE/LOT RELATIONSHIPS
TUMBLER RIDGE

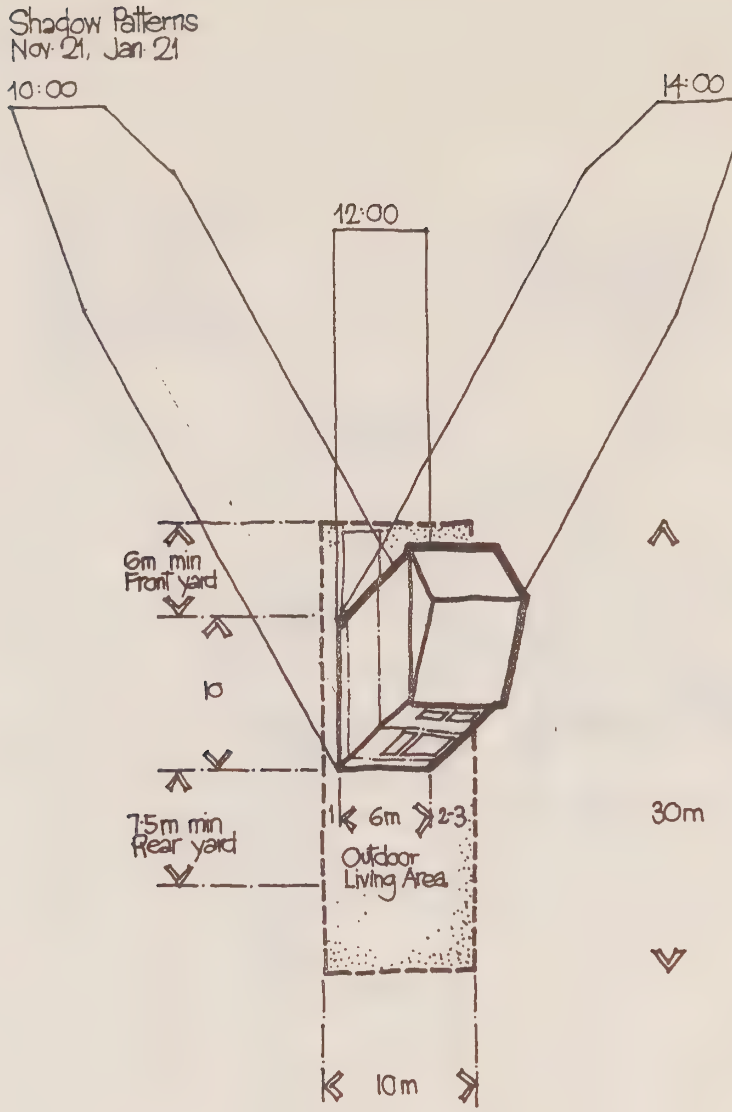


Figure 11

2 STOREY DETACHED 120 m^2 HOUSE/LOT RELATIONSHIPS

TUMBLER RIDGE

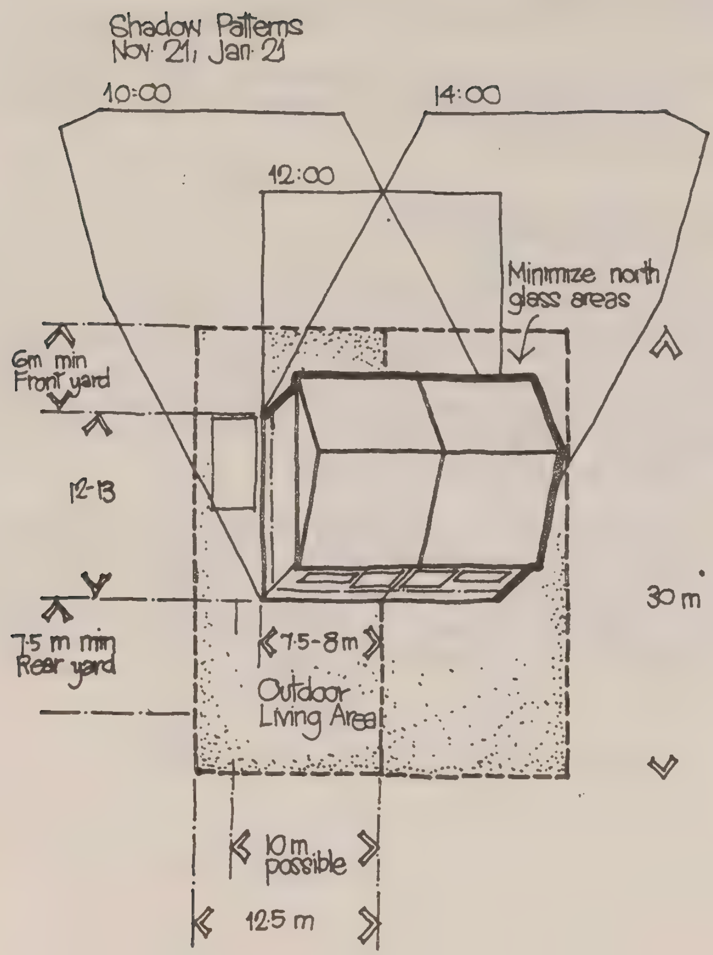


Figure 12

1 STOREY SEMI·DETACHED 195m² (97·5m²/unit) HOUSE/LOT RELATIONSHIPS

TUMBLER RIDGE

Semi-detached units are more land- and energy-efficient than detached housing types, but their acceptability is highly dependent on the degree of sound isolation possible between units.

(13) 1 Storey Semi-Detached, 153 m^2

Minimum lot size: 2 x 10 m x 30 m. A slightly longer frontage, 2 x 12.5m, allows side yard parking.

The smaller unit does not necessarily result in a smaller lot size, since it is shorter along the depth of the lot, rather than narrower along its frontage.

3 storey Walk-Up Apartments

The preferred lotting configuration is one which allows all units to get south, east, or west sun for solar gain. The conventional walk-up form has an internal corridor with two stairs, and 4 units per floor (clusters of 12). When these groups of 12 are linked together in longer buildings, the building axis runs north-south, so that units can have either an east or a west orientation. Parking is usually provided at grade.

Walk-up apartments are potentially energy-efficient in larger groupings because units have the smallest exposed wall area relative to interior floor area. However, some rooms, such as bathrooms and kitchens, may be internal to the unit, and without natural light as provided by other housing types.

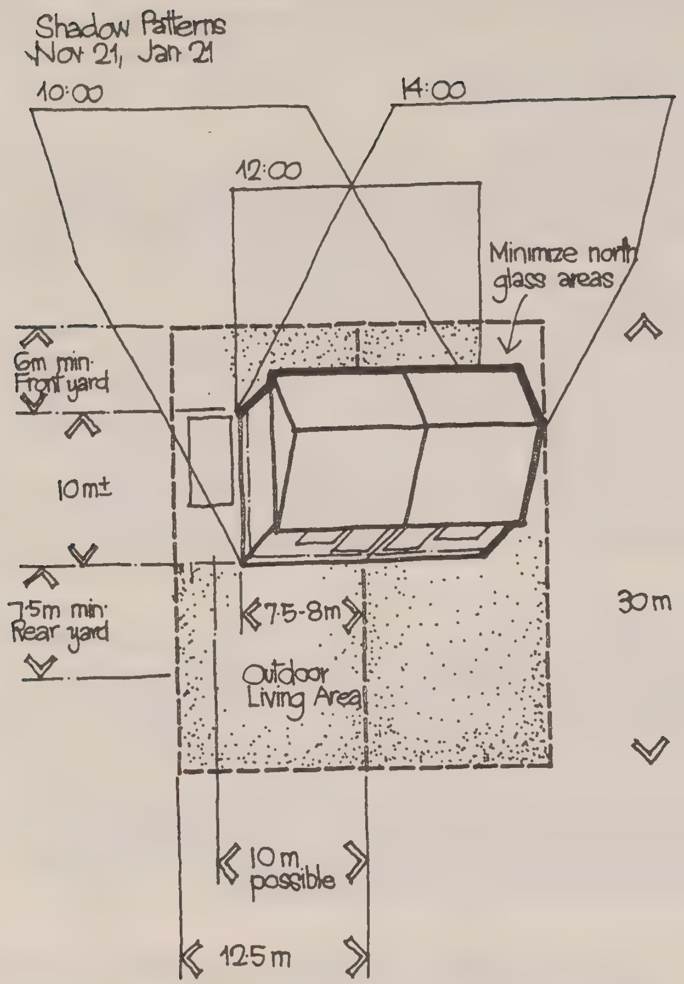


Figure 13

1 STOREY SEMI-DETACHED 153m² (76·5m²/unit)
HOUSE/LOT RELATIONSHIPS

TUMBLER RIDGE

4.2 Housing Clusters

Principles

- Solar Access

  - preserve unshaded solar access to each housing unit between 10:00 AM to 2:00 PM on November 21 or January 21.

- Network Efficiency

  - minimize road length

  - restrict housing clusters to a size which is readily serviced for water supply, district heating piping, traffic, and other utilities.

- Land Efficiency

  - rectangular lot shape and rectangular clusters can be assembled for efficient "space packing", allowing terrain variations to be taken up in the open space system of the community.

Much of the work at this scale concentrated on different arrangements of standard 15 x 30 m lots. The same basic principles hold whether the lots are narrower (12.5 m) or wider (25 m for two 12.5 semi-detached units).

The Cul-de-sac is an efficient lotting arrangement because it economizes on road and services lengths in comparison with loops and other street arrangements, and creates a small social grouping of similar housing types. A number of plans have been developed which illustrate north-south lots for solar access. Even though this orientation need not be used for all housing, conventional culs-de-sac with "pie-shaped" lots (narrow frontage and wide backage) are also economical. The cul-de-sac also requires a narrower right of way (15 m) and road width (8.5 m) than other classes of roads with more traffic.

The cul-de-sac is particularly efficient for a district heating distribution network. Small trenching machines can be used to lay pipes up to 300 mm in overall diameter (corresponding to two 100 mm diameter supply and return pipes in an insulated jacket). This size can serve 24 and up to 30 homes at an installed cost of $200/m.*

For a larger number of houses, more expensive back hoes must be used to lay larger diameter pipe (at least for the initial portions of the distribution network), at costs approaching $600/m or more. Larger diameter distribution lines within the community (generally running along collector and arterial roads), must still be installed using larger equipment.

---

* Source: Cogeneration Associates

Economies are also possible with other services, since the cul-de-sac reduces road length, but since other services are often laid at greater depths (3 m +), the same cost breakpoint in equipment type does not occur.

Certain social benefits such as security against crime have also been claimed for street types such as the cul-de-sac, and dead-end streets. According to Oscar Newman (1972)*, surveillance dampens crime. On short streets such as courts, mews, and culs-de-sac, access is restricted, the street zone is semi-public rather than public, and is overlooked by a small number of residents who come to know each other.

Some criticisms of culs-de-sac have been expressed by local public works departments because they increase equipment turn-around, and may require extra movement for some vehicles such as snow plows. Easements or specific areas may have to be provided for snow deposition by plows. In view of the relatively low operating costs of municipal services/km of road compared with the high carrying charges for the capital cost of the same km of road, these comments cannot be a major impediment to their development and use.

Other lotting arrangements such as east-west streets with loops, north-south streets with "flag-lotting", intercardinal streets, etc., have not been illustrated, although some of them are used in the illustrative plan later in this report. In general, other lotting arrangements are relatively straightforward, but less efficient than the cul-de-sac.

Figures

14. East-West Cul-de-Sac (15 m frontages)

14 lots, asymmetrical arrangement.

A turnaround of 27 to 30 m in diameter is possible, with a central landscaped island, useful for winter snow storage. However, a 24 m diameter turnaround, with the island, is also possible, and more economical.

Split level and 1 storey houses have been illustrated in this pattern, although semi-detached houses on 25 m lots are also feasible, as well as 2 storey houses on 10 m lots (the latter only on the south side of the street because of the long shadows cast at this latitude). Split level houses are particularly adaptable to the north side of the street, because a garage to the south side of the unit does not interfere unduly with solar access.

This pattern also illustrates the use of the "flag lot" at the end of the cul-de-sac, and on north-south streets. This lot has a narrow

---

* Oscar Newman; Defensible Space, (New York, MacMillan, 1972)

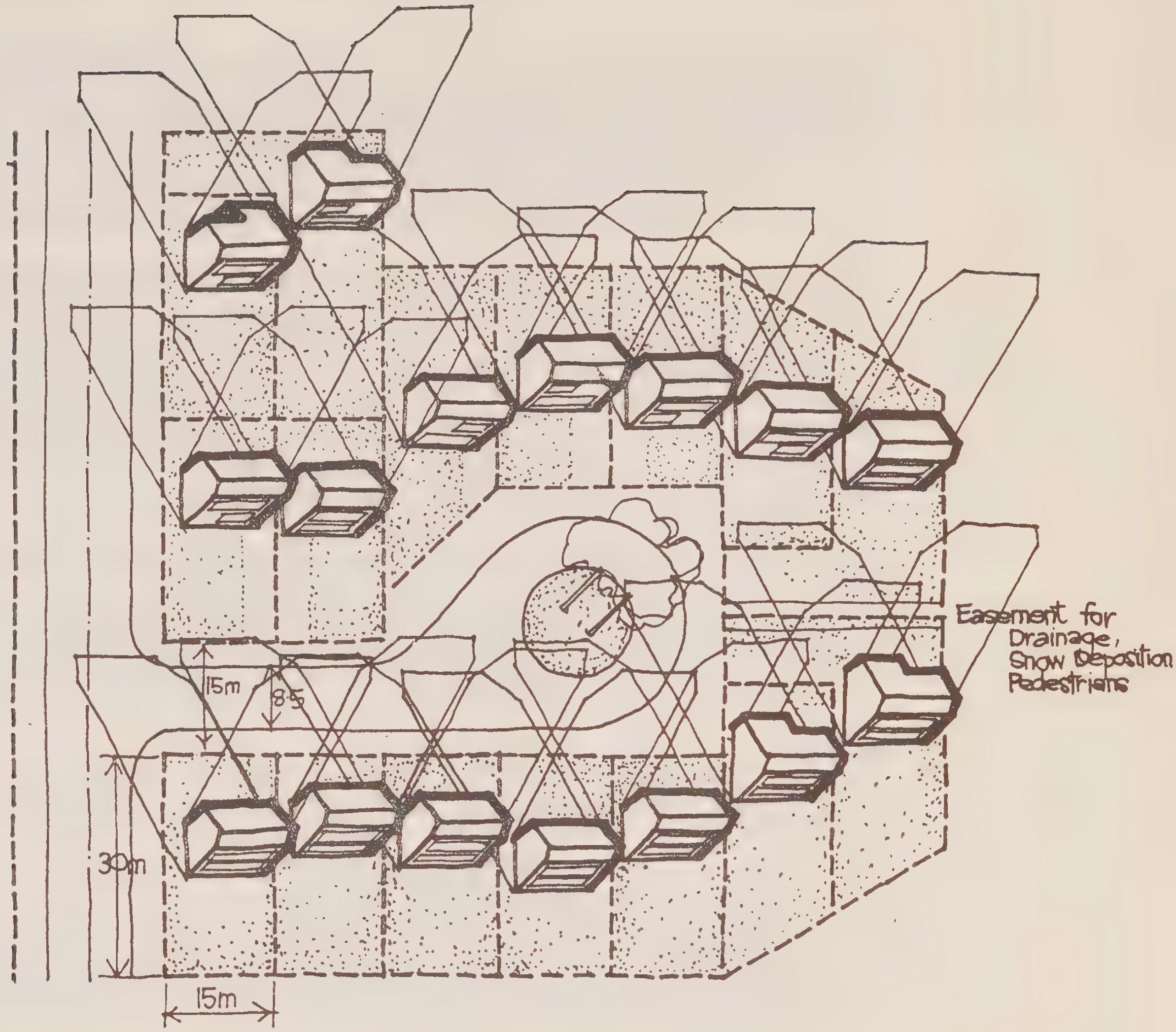


Figure 14
E·W CUL·DE·SAC
HOUSING CLUSTERS
TUMBLER RIDGE
1:1000

street frontage, but a long perimeter, meaning that houses may lack the exposure of conventional lots. This may hinder their acceptance in some communities unless care is taken in site design to locate houses for maximum visibility from the street. Also, flag lots are entered from the side, possibly necessitating some adjustments in house design and entries.

15. Extended East-West Cul-de-Sac (15 m frontage)

    20 lots, asymmetrical arrangement.

    The standard east-west cul-de-sac can be extended; in this case, to 20 lots, with 120 m of road. An extension to 150 m of road length is the practical limit for culs-de-sac , both in terms of the number of houses and cars which a narrow street can accommodate, and in terms of other services, such as the looping of water lines, access for emergency vehicles, etc.

16, Alternative East-West Cul-de-Sac (15 m frontage)

    14 lots, symmetrical arrangement.

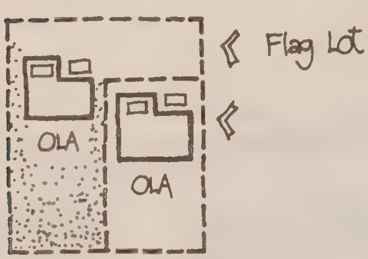
    This arrangement may be more suitable under certain terrain conditions. A smaller 24 m diameter turnaround without central island has been illustrated.

In addition, east-west culs-de-sac with intercardinal streets (i.e. close to, but not precisely east-west in orientation) are also feasible, but have not been shown.

17. North-South Cul-de-Sac (15 m frontage)

    13 lots, symmetrical arrangement.

    This alternative is the most efficient north-south form which maintains solar access. Side access is provided to a number of lots; this permits several cars to be parked on a lot to the north side, without interfering with an outdoor living area to the south of the unit.



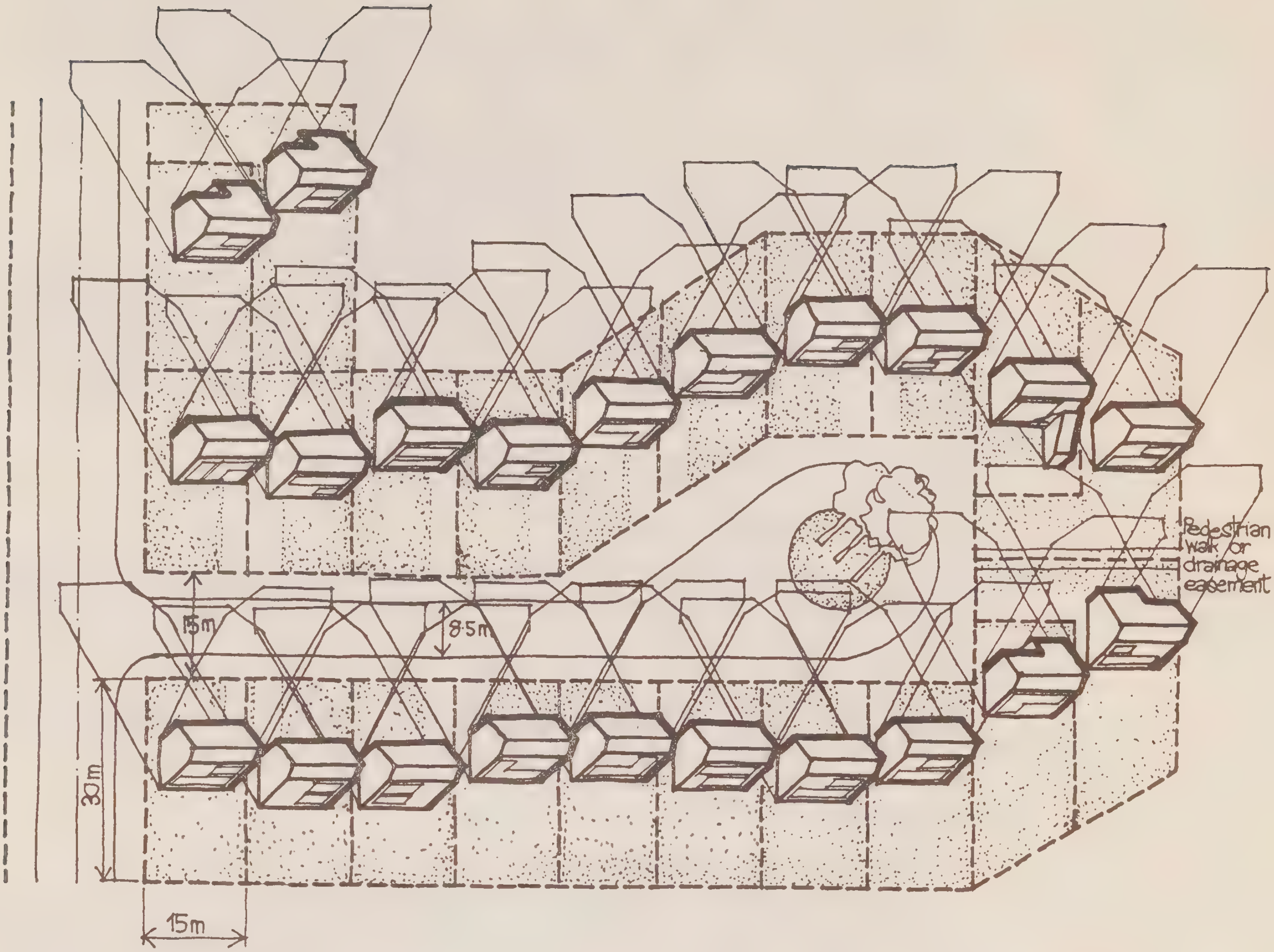


Figure 15

EXTENDED E·W CUL·DE·SAC HOUSING CLUSTERS

TUMBLER RIDGE

1:1000

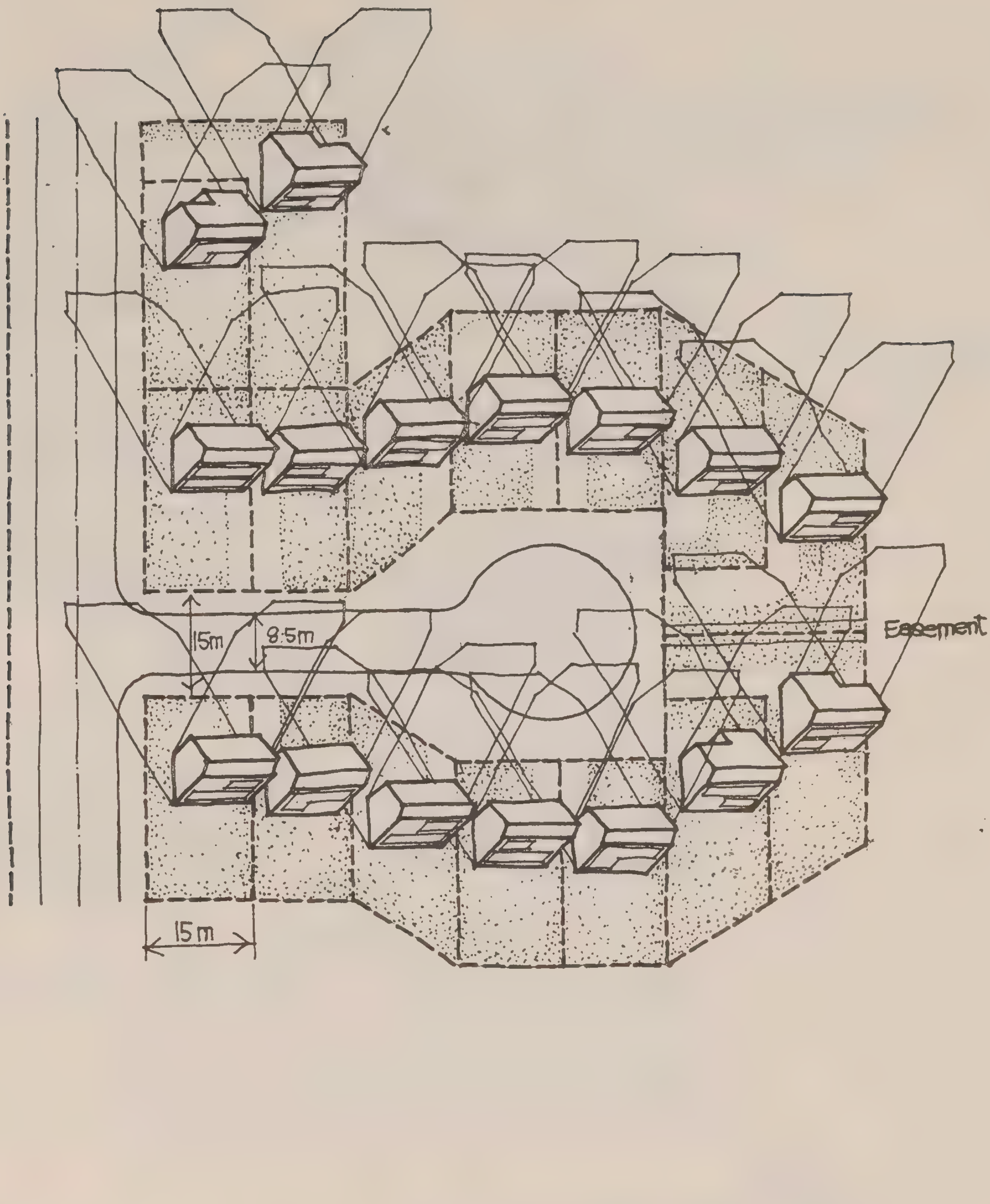


Figure 16

ALTERNATIVE E·W CUL·DE·SAC HOUSING CLUSTERS

TUMBLER RIDGE

1:1000

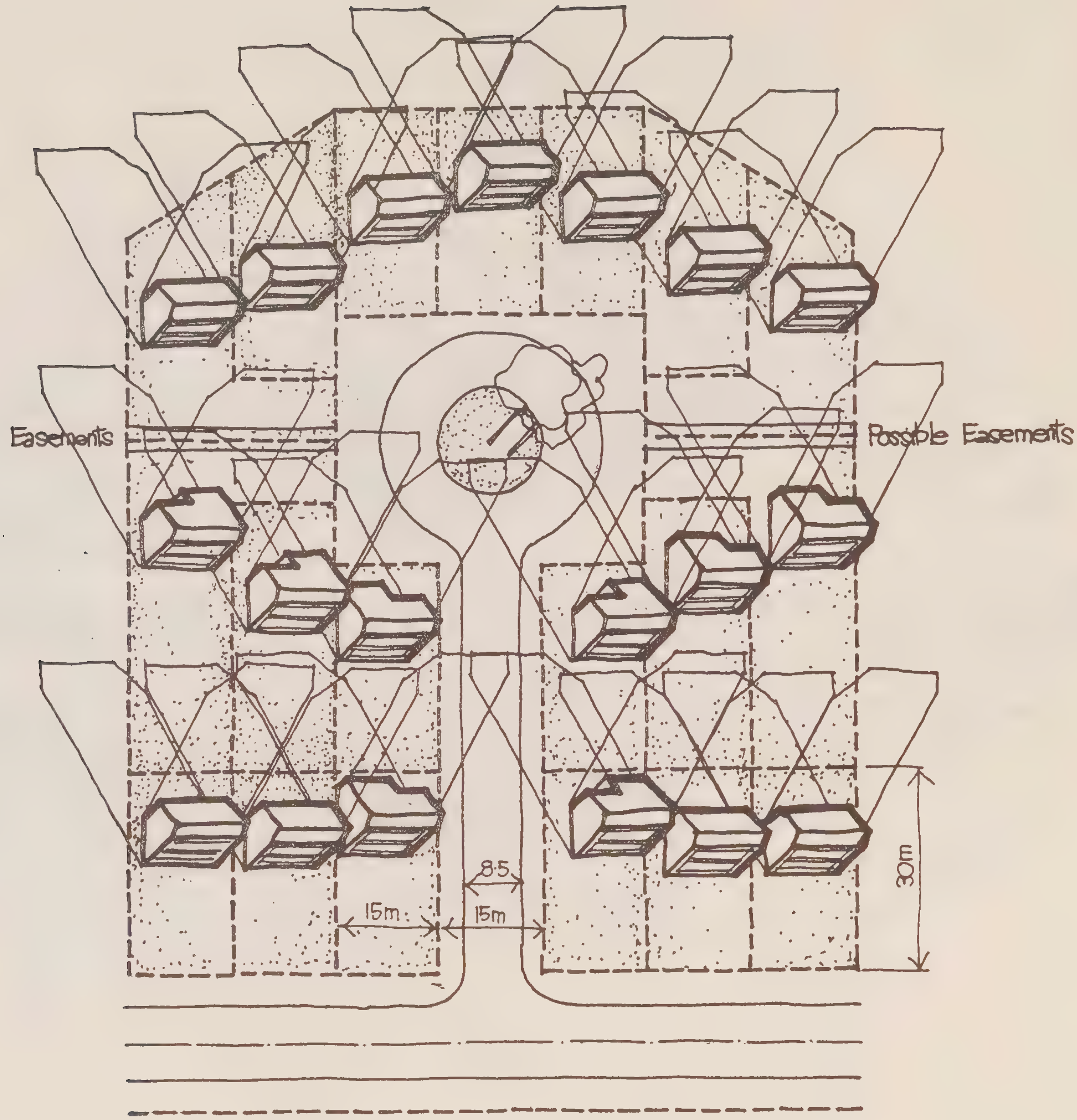


Figure 17
N·S CUL·DE·SAC
HOUSING CLUSTERS
TUMBLER RIDGE
1:1000

18. Short North-South Cul-de-Sac (15 m frontage)

7 lots, symmetrical arrangement.

This layout is useful in restricted conditions, although slightly less efficient than Fig 17. In actuality, access is provided to 11 lots from the turnaround, because it makes better use of lots which apparently front on the collector street.

19. North-South Cul-de-Sac (12.5 m frontage)

13 lots, symmetrical arrangement.

Reductions in lot width have little effect on road or servicing lengths compared with Figure 17, although less land area overall is required. Narrower lot widths may necessitate zero lot line layouts in order to permit some flexibility in arranging houses on the lots to prevent overshadowing negihbours.

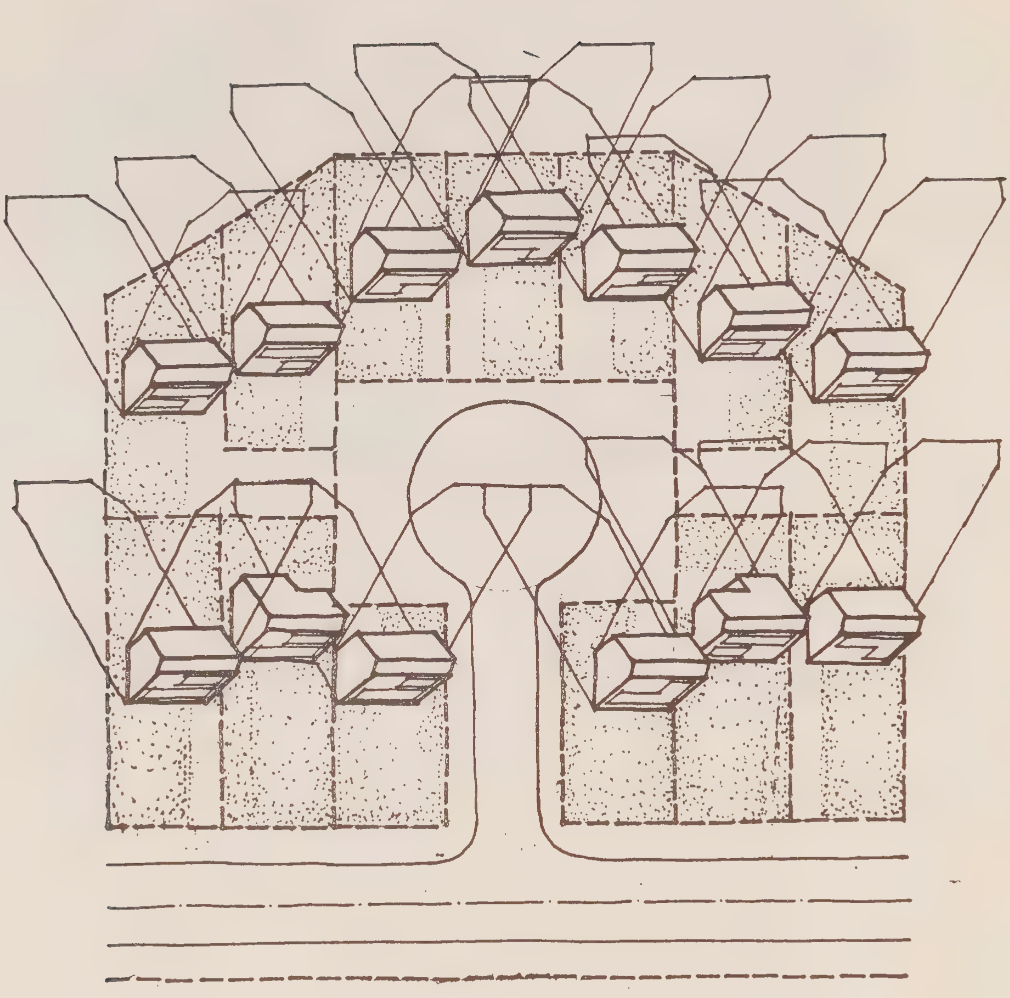


Figure 18

SHORT N·S CUL·DE·SAC
HOUSING CLUSTERS

TUMBLER RIDGE

1: 1000

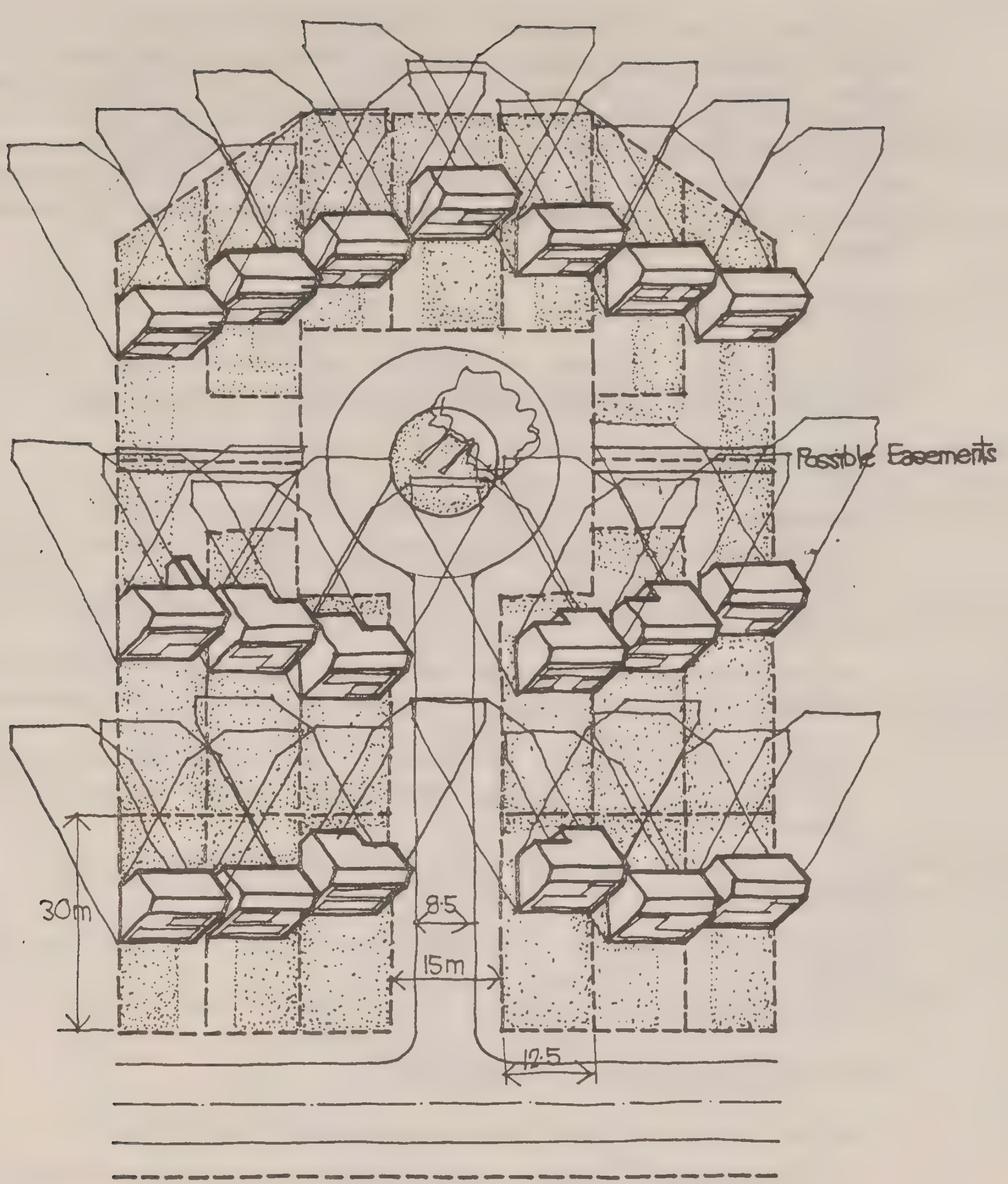


Figure 20
N·S CUL·DE·SAC (12·5m frontage)
HOUSING CLUSTERS
TUMBLER RIDGE

4.3 Community Layout

This study is being introduced in a planning and construction process already underway at Tumbler Ridge. At the community layout scale, a number of major roads, the Town Centre, and two neighbourhoods were already planned and under construction. Therefore, work at this scale concentrated on developing proposals for new subdivision areas to the north and east sides of the community, where planning was not finalized, together with suggestions for feasible modifications to areas already planned.

Principles

- Solar Access - achieved through correct orientation of housing clusters and roads (predominantly north-south or east-west).

- Wind Protection:

  - retention of major wind-firm shelter belts (100 m ± wide) on terrace edges, with intermediate belts as required. Housing clusters placed to the lee (sheltered) side of these belts; major roads to the windward (exposed) side of shelter belts to minimize snow drifting.

  - orientation of major open space and pedestrian routes away from predominant wind directions (which are south and south-west).

  - minimizing the number of local street and paths oriented in the prevalent wind directions (east-west, or north-west to south-east should predominate).

- Environmental

  - avoidance of steep slope and hazard lands for housing and roads

  - minimizing the crossing or traversing of such areas.

- Network Efficiency: Transportation

  Tumbler Ridge has four major road classifications:

  1) the Chetwynd - Dawson Creek Highway which loops around the south and east sides of the community;
  2) two north-south arterial roads which parallel the terrace edges;
  3) collector roads serving each neighbourhoods, with some frontage;
  4) local roads, with the bulk of the housing frontage.

  In a small community, the major home-based trip purposes are:

  - Work (mines), along collectors (3) to arterials (2) to Highway (1)
  - Town Centre, along collectors (3) to Town Centre
  - School (walking), along local roads (4) and pedestrian paths to school.

At this scale, the most important planning principles are:

- Minimizing Trip Length, achieved by

  Compact community form, centred around the Town Centre

  Direct radial collector roads to the Town Centre from each neighbourhood, to minimize trip lengths for shopping, recreation, and similar trip purposes

  Direct access from arterials to the highway, to minimize work trip length

  Sheltered pedestrian routes (not crossing arterial roads) from each neighbourhood to schools.

- Encouraging energy-efficient transportation modes

  Walking: placing the bulk of the highest density development (walk-up apartments) within walking distance (300 m) of the Town Centre; providing shelter and direct building linkages where feasible.

  Wind protected pedestrian routes to each school.

  Transit: collector roads within each neighbourhood: all housing within a 300 m walking radius of collector roads used for transit routes.

  Linking collector roads between each neighbourhood so that an easy circuit of the entire community can be developed.

These principles are illustrated in two maps:

4.31 Development Constraints: a summary and analysis of terrain and vegetation data prepared by Provincial agencies and Tumbler Ridge consultants. (Figure 21)

Three categories of development constraint areas are defined:

1) Major: steep slopes, greater than 15%
   - no building
   - minimize vegetation removal
   - minimize earthmoving, and road crossing points.

2) Moderate: escarpment setbacks, moderate slopes (10 - 15%), lodgepole pine forests to the north side of the town site (high fuel loadings, fire hazard unless cleared)
   - no building
   - some roads possible

3) Minor: some added costs for earthmoving for drainage; slopes 5 - 10%
   - buildings, roads, services permitted.

No Constraints: (blank areas on map) fully buildable.

/ Cont

Figure 21

DEVELOPMENT CONSTRAINTS
TUMBLER RIDGE

The "major" constraint areas are also reproduced on the community plan which follows.

4.32 Suggested Modifications to the Conceptual Plan

These modfications are based on the design patterns developed in this report. Concepts are developed for new neighbourhoods to the north and east of the Town Centre. Minor changes are suggested for the road network in the present plan. (Figure 22)

The principles followed are those already mentioned: (Figure 23)

- Solar Access - correct lot and road orientations
- Wind Protection
  - retention of ridge shelter belt to the east side of the community + new intermediate shelter belt to the north
  - location of open space and residential areas to the lee side of shelter belts, within the wind protection zone
- Environmental
  - avoidance of major constraint areas for housing; minimize crossing by roads
- Network Efficiency
  - compact community form
  - direct radial roads to the Town Centre
  - higher density apartments within walking distance (300 m) of the Town Centre
  - location of schools in the centre of catchment areas to encourage walking to school, without crossing arterial roads.

Conceptual Plan

Figure 22

TUMBLER RIDGE

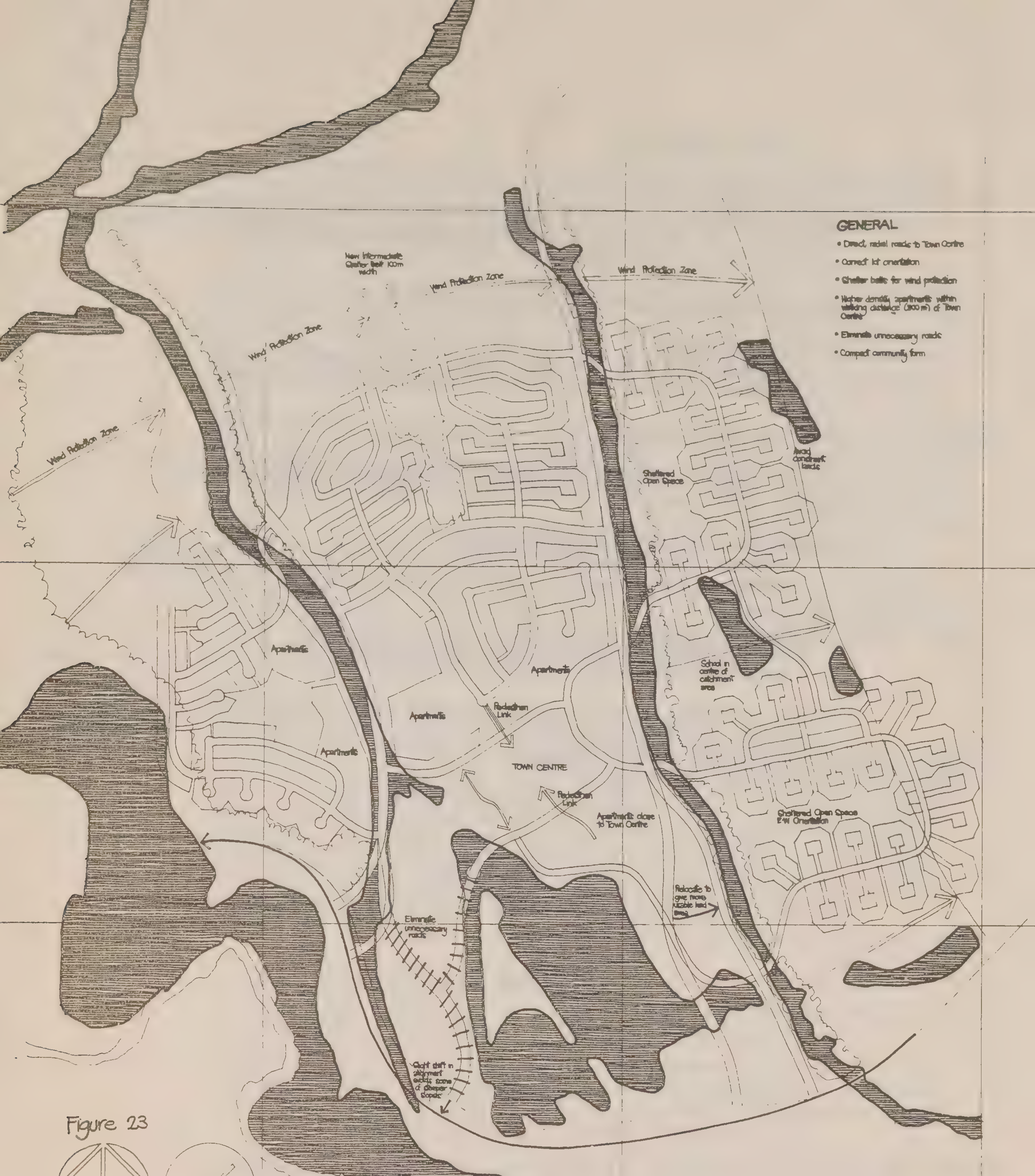


Figure 23

SUGGESTED REFINEMENTS
TUMBLER RIDGE

5. COSTS & BENEFITS

In this chapter, the costs and benefits of the design patterns are assessed. Design patterns to reduce space heating costs are analysed at the scale of the individual unit:

- Solar Access: increases internal heat gain

- Wind Protection
  - reduces infiltration and transmission losses
  - improves outdoor environment (non-quantifiable benefit)

The combined effect of these two factors is also estimated.

The principles of land efficiency and network efficiency, because of their complexity, are assessed at two levels of detail:

- Housing Clusters/Subdivision Layout
  - reduces site preparation, roads, and services capital costs
  - reduces transportation operating costs (internal, local roads)

- Community Layout
  - reduces road network capital costs (arterial)
  - reduces transportation operating costs (arterial and external roads).

Where possible, these cost savings have been estimated by comparing a preferred or improved alternative with a Plan or part of a Plan already developed for Tumbler Ridge.

5.1 Solar Access

The value of site planning for solar access lies not in the benefits of passive solar gains in reducing space heating energy to be purchased, per se, but in the differences between the passive solar gains achieved by alternative units orientations.

For example, over the heating season, a small (88 m^2) detached house of standard construction can have useful passive solar gains as high as 17 GJ, a major percentage of the annual "wild" internal heat gains, and a substantial proporation of the heating energy needs to be purchased (which are 81 to 84 GJ for this house type, at Tumbler Ridge).

However, any orientation of the same housing unit will receive at least some passive solar gains; therefore, the critical consideration is the difference in solar gain between the "best" and an "average" orientation. In the "best" orientation, 50% of the unit window glass area faces south; in an "average" orientation, only 1/6 to 1/4 (16 - 25%) of the window area of the unit is located on its south face.

In the case of the small detached house, the differences in solar gain between these two orientations is 5.5 GJ annually at Tumbler Ridge. This value is a substantial percentage of the solar gain (47%), but a modest percentage of space heating needs (5 - 7%).

5.11 Modelling

To predict the effects of different unit orientations on space heating requirements, the results of the Saskatchewan Research Council report on energy-efficient housing were taken as representative of good passive solar design, with 50% of the window area facing south, for all unit types (detached, attached, townhouses, apartments, and manufactured homes). The "average" orientation was modelled with the CMHC2 heat loss model by CMHC's Technical Research Division, Ottawa, for different qualities of construction*. Results were estimated for

---

* Quality of construction definitions:

- Standard: conventional 2 x 4 wood frame, wall insulation RSI 2.1, ceiling insulation RSI 3.5, standard vapour barrier
- "Measures": construction to levels recommended in the 1980 NBC: Measures for Energy Conservation in New Buildings: wall insulation RSI 3.5, ceiling RSI 5.6, basement RSI 1.4, standard vapour barrier, improved windows and other components.
- Retrofit-Ready: energy conservation measures that can be implemented during initial construction at reasonable cost, but would be expensive as retrofit work: wall insulation RSI 4.9, ceiling RSI 7.1, basement RSI 1.6, air tight vapour barrier & air management system.
- Super Energy-Efficient: wall insulation RSI 7.1, ceiling RSI 10.6, basement RSI 4.9, air vapour barrier, air management system with heat recovery unit, thermal doors with storms, triple glazed windows

other unit types, extrapolated from these modelled results.

The results of this comparison are summarized in Figure 24 , Effects of Orientation on Passive Solar Design, and the 1982 monetary values calculated for Natural Gas (65% efficient furnace) and Electrical Heating. The Saskatchewan Research Council results for the same comparison, for the large single detached unit only, are higher (80%+) than the CMHC2 model results. These are termed "optimistic" compared with the "conservative" results of the CMHC2 model. These "optimistic" energy savings were extrapolated and calculated for all unit types. Such savings should be feasible if housing units are further adapted for passive solar design, by including mass within the unit for thermal storage, and providing (and using) night time insulating shutters for all windows.

In addition, the CMHC2 model was run under the assumption that the units faced south, but solar access was partly blocked by nearby units, as occurs in some lots in existing neighbourhoods. A blocked unit facing south had similar heat requirements to a unit with "average" orientation. Therefore, it appears that the benefits of passive solar gain can only be realized if two conditions are satisfied: the unit is oriented correctly on the lot and is not blocked; and windows are placed appropriately in the unit so that as much glass area faces south as possible. Figure 24 then, represents the community-wide energy savings from good unit orientation and window placement, vs. a layout in which unit orientation or window placement are poor.

In the present analysis, all windows except those facing north receive some solar gain by day, and all lose equivalent amounts of heat by night during the heating season. The full benefits of solar gain can only be realized by the use of insulating shutters to reduce this night time heat loss. This has not been modelled.

In reviewing Figure 24 , it can be seen that the more energy-efficient forms of construction (retrofit ready, and super energy-efficient) make less use of passive solar gain in absolute terms in comparison with standard and measures construction. This occurs for several reasons:

- energy-efficient units are more isolated from the external environment
- they have a shorter heating season and smaller heat needs to be offset by solar gains (i.e. more of the incoming solar gain is "dumped" or lost, than with less efficient types of construction).

However, because of their lower heat needs in general, the percentage contribution to heat load made by correct solar design increases dramatically, from 4.2% in the standard house, to 7.8% in the super energy-efficient house. Under "optimistic" solar gain assumptions, this percentage contribution ranges from 7.6% for standard construction to 14.0% for super energy-efficient construction. This is outlined in Figure 25.

Figure 24

Effects of Orientation for Passive Solar Design

Annual Savings in GJ Between Best and Average Orientations
Applied Across the Entire Community

Unit Type	Number	Standard	Measures	Retrofit	E - E
Large Single*	511	(5.5) 2,810.5	(5.5) 2,810.5	(4.1) 2,095.1	(1.9) 970.9
Small Single*	510	(5.5) 2,805	(4.1) 2,091	(3.8) 1,938	(3.0) 1,530
Large Duplex*	68	(4.0) 272	(3.9) 265	(3.5) 238	(2.0) 136
Small Duplex	67	(3.1) 210	(3.0) 205	(2.8) 184	(1.6) 105
Row Townhouses	112	(3.1) 347	(3.0) 336	(2.8) 308	(1.5) 168
Apartments	738	(1.0) 738	(1.0) 738	(1.0) 738	(0.5) 369
Manufactured	388	(4.0) 1,552	(4.0) 1,552	(4.0) 1,552	(4.0) 1,552
	2,394				
Total GJ "Conservative"		8,734.5 GJ	7,997.5 GJ	7,053.1 GJ	4,831 GJ
"Optimistic" (+80%)		15,722	14,395.5	12,696	8,696
Conservative 1982 $ Value					
NG, 65% Furnace @ $7.50/GJ		$65,508.75 $27.36/du	$59,981.25 $25.05/du	$52,898.25 $22.10/du	$36,232.50 $15.13/du
Electrical @ $10.21/GJ		$89,179.25 $37.25/du	$81,654.48 $34.11/du	$72,012.15 $30.08/du	$49,324.51 $20.60/du
Optimistic 1982 $ Value					
NG, 65% Furnace @ $7.50/GJ		$117,915.00 $49.25/du	$107,966.25 $45.10/du	$95,220.00 $39.77/du	$65,220.00 $27.24/du
Electrical @ $10.21/GJ		$160,521.62 $67.05/du	$146,978.05 $61.39/du	$129,626.16 $54.15/du	$88,786.16 $37.09/du

* CMHC2 Model results, other values estimated

Figure 25

Base Case: Good Solar Design, 7.5 km/h Wind

Annual Space Heating Requirements in GJ
(source: SRC Revised Report 2)

Unit Type	Number	Standard	Measures	Retrofit	E - E
Large Single	511	(130) 66,430	(85) 43,435	(72) 36,792	(34) 17,374
Small Single	510	(103) 52,530	(65) 33,150	(53) 27,030	(21) 10,710
Large Duplex	68	(100) 6,800	(64) 4,352	(52) 3,536	(21) 1,428
Small Duplex	67	(77) 5,159	(49) 3,283	(38) 2,546	(13) 871
Row Townhouses	112	(73) 8,176	(44) 4,928	(34) 3,808	(8) 896
Apartments	738	(25) 18,450	(24) 17,712	(12) 8,856	(2) 1,476
Manufactured	388	(127) 49,276	(76) 29,488	(76) 29,488	(76) 29,488
	2,394				
Total GJ		206,821	136,348	112,056	62,243
Percentage contribution of correct orientation for passive solar gain:					
"Conservative"		4.2%	5.8%	6.3%	7.8%
"Optimistic"		7.6%	10.4%	11.3%	14.0%

5.2 Wind Protection

Winds on the Tumbler Ridge townsite blow consistently throughout the year, largely from the south and south-west, due to channelization up the Murray River valley.

On the Ridge itself, winds consistently average 15.8 km/h to 18.7 km/h from the south-west, and 12.4 km/h to 17.1 km/h from the south. (Figure 26) Winds from these two directions are blowing for more than 60 to 70% of the time, throughout the year. Gusts approaching 40 km/h or more are also a factor, more so in winter than in summer.

Since much of the site will be cleared of tree cover for construction purposes, the effects of wind on both the Town Centre and exposed residential areas, are likely to be significant. Amelioration of the outdoor environment will be particularly important in encouraging walking to destinations or to public transit stops. Without it, snow drifting and wind chill are likely to be severe.

Amelioration of the outdoor environment is difficult to quantify in economic terms. However, the effects of wind protection on space heating can be estimated approximately.

5.21 Space Heating Effects

The effects of wind modification on building heat loss are complex to measure and analyse for existing buildings, let alone predict, with accuracy, for buildings not yet constructed. Important variables include:

- Characteristics of the house: air tightness, sheltering by other houses, chimneys and fireplaces

- Characteristics of the wind: wind speed and constancy; temperature differential between exterior and interior

- Modifications taken to reduce wind: actual reductions in wind speed, distance or area over which these reductions are effective.

Wind affects space heat losses by infiltration through cracks in the building (doors and windows in particular) and transmission: heat transfer through components of the building envelope.

Infiltration losses are a significant percentage of building heat losses: 25% for the standard house; 15 to 20% for the upgraded (NRC measures) house; and vary with the air tightness of the building, the wind pressure (speed), and temperature differential pressure. Recent empirical tests by the National Research Council (C.Y. Shaw; Correlation Between Air Infiltration and Air Tightness for Houses in a Developed Residential Area, 1981) indicate that wind pressure on the upgraded (NRC measures) house is largely offset by temperature differential pressure when $\triangle t$ is greater than 20°C (as occurs in winter) for a wide range of wind speeds, 10 to 25 km/h.

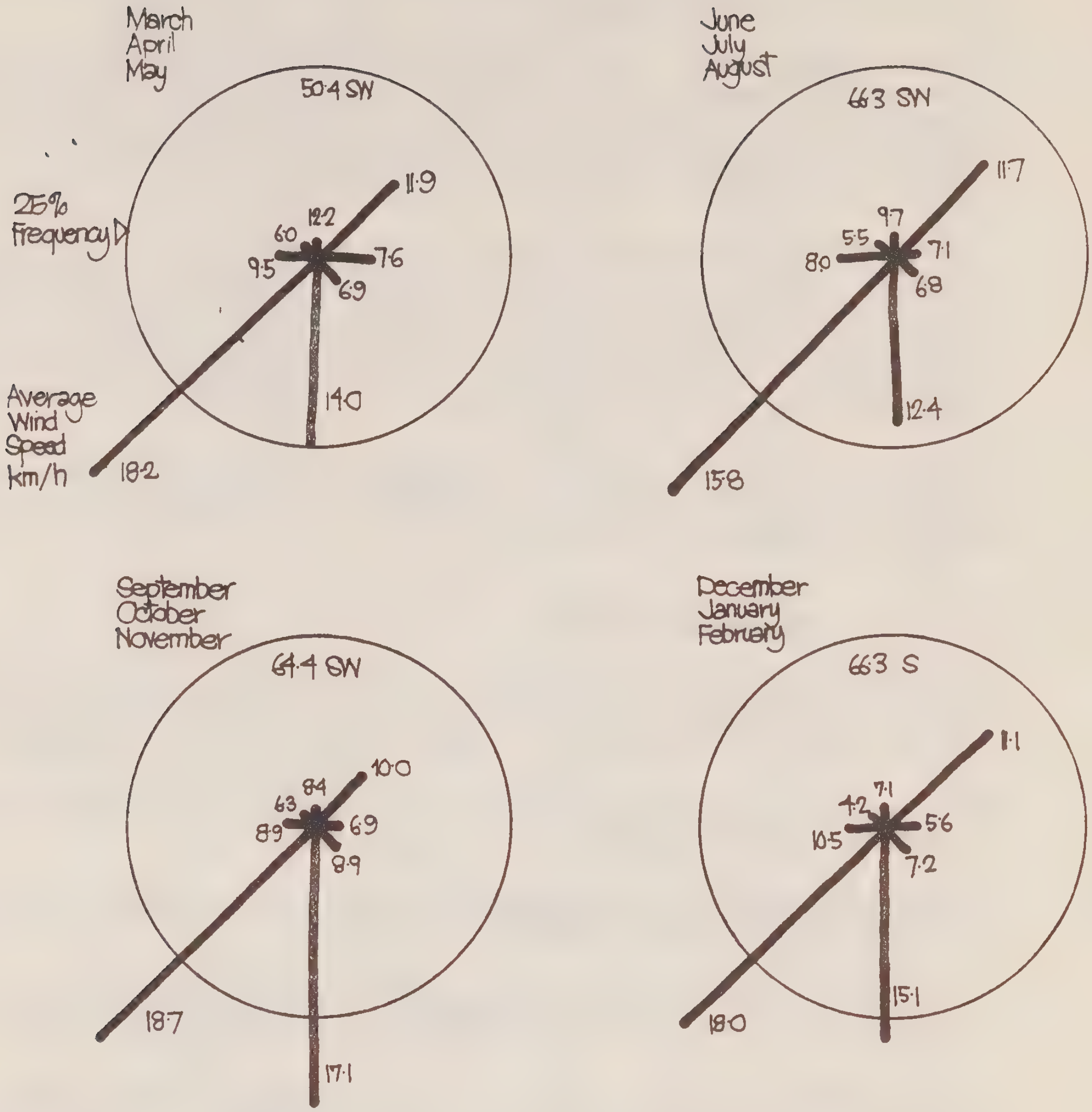


Figure 26

WIND ROSES TUMBLER RIDGE

SOURCE: AIR STUDIES BRANCH
B·C· MINISTRY OF ENVIRONMENT
1976-78

Earlier work by Shaw and Tamura (Air Tightness and Air Infiltration Measurements, NRC Building Research Note # 102, June, 1980) suggests that the effects of wind pressure on infiltration are difficult to predict because of data scatter, particularly for large Δt. At best, the differences in infiltration between wind speeds from 7 to 25 km/h are likely to be no more than 0.1 air changes per hour, when the inside/outside temperature differences are greater than $10^{o}C$.

Some publications (e.g. Robert Socolow Saving Energy in the Home, 1978) claim that the effects of wind amelioration by planting trees close to the house could be as high as 0.2 air changes per hour. However, these results were apparently not controlled for temperature differential. In fact, reductions in infiltration are not desired in summer when more ventilation is required, and energy use is not affected.

Other work, notably by the Ontario Ministry of Energy (Saving Energy by Way of Site Design, 1981) suggests in theoretical form that the effects of wind on infiltration loss may be significant, but again, there are no empirical results to confirm this.

Transmission losses through the components of the building envelope can be affected by high wind speeds which strip away the insulating value of the air film around the house. However, only the windward side of the building is affected, not the lee (sheltered) side. The roof is also not affected because of the layer of stagnant (dead) air above the attic. The value of the air film is also relatively small: for example, the thermal resistance of a wall under still conditions might be R 10.68, and under 15 km/h winds, R 10.17. The value of this still air film then, is only R 0.5, or 4.7% of the wall's thermal resistance.

The effects of wind amelioration at Tumbler Ridge on space heating losses were approximated by:

- reducing infiltration losses by 0.1 air changes per hour

- applying the full insulating value of the air film for the 0 km/h condition, with no value on the windward faces for the 15 km/h wind condition.

This assumes that the maximum potential effect (a reduction from 15 km/h to 0 km/h) can be achieved by shelter belts and other means.

The results of this analysis by the CMHC2 model run by the CMHC Technical Research Division, are presented in Figure 27: Effects of Wind Shelter. While these results appear to be significant, they must also be qualified:

1. Tumbler Ridge's average wind speed of 15 - 18 km/h. although relatively consistent throughout the year, will still vary somewhat, with both gusts and still periods. Therefore the high value for wind speed may be unrealistic, as well as its potential reduction to 0 km/h by various landscaping measures. There will always be some air movement around the house.

Figure 27

Effects of Wind Shelter (15 km/h Reduced to 0 km/h)
Annual Savings in GJ

Unit Type	Number	Standard	Measures	Retrofit	E - E
Large Single*	511	(12.3) 6,285.3	(12.0) 6,132	(2.3) 1,175.3	(1.2) 613.2
Small Single*	510	(10.2) 5,202	(9.8) 4,998	(1.8) 918	(0.9) 459
Large Duplex*	68	(11.0) 748	(10.6) 720.8	(1.9) 129	(0.9) 61.2
Small Duplex	67	(8.5) 570	(8.1) 542.7	(1.4) 93.1	(0.6) 37.5
Row Townhouses	112	(8.0) 896	(7.3) 871.6	(1.2) 138.9	(0.3) 38.1
Apartments**	738/2	(1.4) 1,018	(2.0) 1,476	(0.2) 147.6	(0.04) 29.5
Manufactured	388	(12.0) 4,656	(10.7) 4,163.2	(10.7) 4,163.2	(10.7) 4,163.2
	2,394				
Total GJ		19,375.3	18,850.3	6,765.1	5,401.7
1982 $ Value					
NG, 65% Furnace @ $7.50/GJ		$145,314.75 $60.70/du	$141,377.25 $59.05/du	$50,738.25 $21.19/du	$40,512.75 $16.92/du
Electrical @ $10.21/GJ		$197,821.81 $82.63/du	$192,461.56 $80.39/du	$69,071.67 $28.85/du	$55,151.36 $23.04/du

* CMHC2 Model results; other values estimated

** Only ½ of units are exposed to the wind, the others are in the lee of the wind.

2. The value of wind protection goes down as the air tightness of the house is improved. The standard and measures houses are relatively porous, the retrofit-ready and super energy-efficient houses are relatively tight and protected from the outside environment. Whether or not the house has a chimney is also an important factor affecting the infiltration rate.

3. The value of wind protection is primarily on the perimeter (edges) of neighbourhoods and housing clusters. Edge (exposed) houses on a street tend to shelter internal houses. In low density (rural) areas, the individual building form is the only form that the wind can "see". In suburban and urban areas, each building becomes a detail in a group form which the wind tends to pass over to a large extent.

4. Even with wind tunnel tests, it would be difficult to predict what effect tree shelter belts and building placement will have on wind speed. At Tumbler Ridge, two kinds of wind shelter are possible:

   - Major Tree Belts: (100 m + in width) at terrace edges. The exposed vegetation edges are wind firm, and with existing tree heights of 20 - 25 m, the effects of wind shelter should extend for a considerable distance, up to 400 m.

     These trees already exist, and their retention is free; by avoiding these areas during construction. However, some costs of vegetation management would be incurred. The location of major shelter belts need not interfere with solar access to buildings.

   - House-related vegetation incurs an added cost because it must be planted and may take a number of years to reach a size for effective wind shelter. Planting close to the unit may also interfere with passive solar gain, since the predominant winds and sun come from the same direction at Tumbler Ridge. The potential effects of such planting on reducing wind speeds are difficult to assess: some literature suggests that dense plantings of conifers at least 2 to 3 rows deep are necessary to have any measurable value in preserving the insulating air film around the house.

   Therefore, major tree belts are the preferred form of wind shelter for Tumbler Ridge.

5.3 Combined Solar Access and Wind Shelter Effects

A conservative and realistic target for wind amelioration is probably in the order of 50% of the energy savings calculated in Figure 27 . When combined with the energy savings for solar access, even these reduced wind values have a measurable effect on heat loads, particularly for the less energy-efficient housing types. The solar access and wind reduction savings can be combined because the "good" solar design case assumes an exposed house with a major wind component, one capable of reduction by sheltering. Also, if the use of major tree shelter belts is assumed, rather than vegetation close to the housing unit, there should be little blockage of solar access.

The combined effects of solar access and wind protection are arrayed in Figure 28 , using both "conservative" (CMHC2 model results) and optimistic (SRC results) solar access values. The potential contribution of both measures ranges from 9 to 18% of the heat loads to be purchased, depending on the quality of construction. As the energy efficiency of construction improves, the percentage contribution of wind shelter goes down, but that of solar access increases.

Figure 28

Combined Effects of Wind Shelter and Solar Access

Annual Energy Savings in GJ

	Standard	Measures	Retrofit	E - E
Solar Orientation "Conservative"	8,734.5 GJ	7,997.5	7,053.1	4,831.0
50% of Wind Shelter	9,687.5	9,425	3,382.5	2,701.0
Total GJ	18,422.2	17,422.5	10,435.6	7,532
1982 $ Value				
NG, 65% Furnace @ $7.50/GJ	$138,166.50 $57.71/du	$130,668.75 $54.58/du	$78,267.00 $32.69/du	$56,490.00 $23.60/du
Electrical @ $10.21/GJ	$188,090.66 $78.57/du	$177,883.72 $74.30/du	$106,547.47 $44.51/du	$76,901.72 $32.12/du
Percentage of Total Heat Load	8.9%	12.7%	9.3%	12.1%
Solar Orientation "Optimistic"	15,722 GJ	14,395.5	12,696	8,696
50% of Wind Shelter	9,687.5	9,425	3,382.5	2,700.9
Total GJ	25,409.7	23,820.5	16,078.5	11,396.9
1982 $ Value				
NG, 65% Furnace @ $7.50/GJ	$190,572.75 $79.60/du	$178,653.75 $74.62/du	$120,588.75 $50.37/du	$85,476.75 $35.70/du
Electrical @ $10.21/du	$259,433.00 $108.37/du	$243,207.30 $101.59/du	$164,161.48 $68.57/du	$116,362.30 $48.61/du
Percentage of Total Heat Load	12.3%	17.3%	14.3%	18.3%

5.4 Subdivision Design

Parts of two alternative subdivision layouts were compared to determine the impacts of compact lot and road configurations.

A representative portion of a neighbourhood already under construction was selected, with largely single family detached housing units (94), some duplex units (14) and 3 manufactured homes, for a total of 109 units (Figure 29). Parks, schools, and collector roads without frontage were not included, to simplify the analysis. The road layout is primarily a grid form, and lot frontages range from 18 to 20 m for detached, 25 m for 2 duplex units, to 12 m for single manufactured homes. No apartments are included in the area selected.

A comparable portion of a neighbourhood based on the design patterns was also developed. This consists of 108 single family detached lots with frontages of 15 m and depths of 30 m (Figure 30). The plan would be slightly more compact if 14 single family lots @ 15 m frontage were replaced by 7 duplex lots (@ 25 m lot width for 2 units), but the differences are slight. The plan is organized with 1 collector road and 6 cul-de-sacs. All lots have north-south orientation and unshaded solar access (the benefits of which are calculated above). Pedestrian access routes, parks, schools, etc. are not part of the plan, but could be readily introduced at several points.

5.41 Cost Analysis

- Road Capital Costs

Part of Neighbourhood 1 - 109 units

Local roads	1 410 m @ $854	1,204,140
Collector	470 m @ $936	439,920
	1 880 m = 17.2 m / unit	1,644,060
	Unit cost = $15,083.12 / unit	

Cul-de-Sac Layout - 108 units

Local roads	610 m @ $854*	520,940
Collector	230 m @ $936	215,280
	840 m = 7.78 m / unit	736,220
	Unit cost = $6,816.85 / unit.	

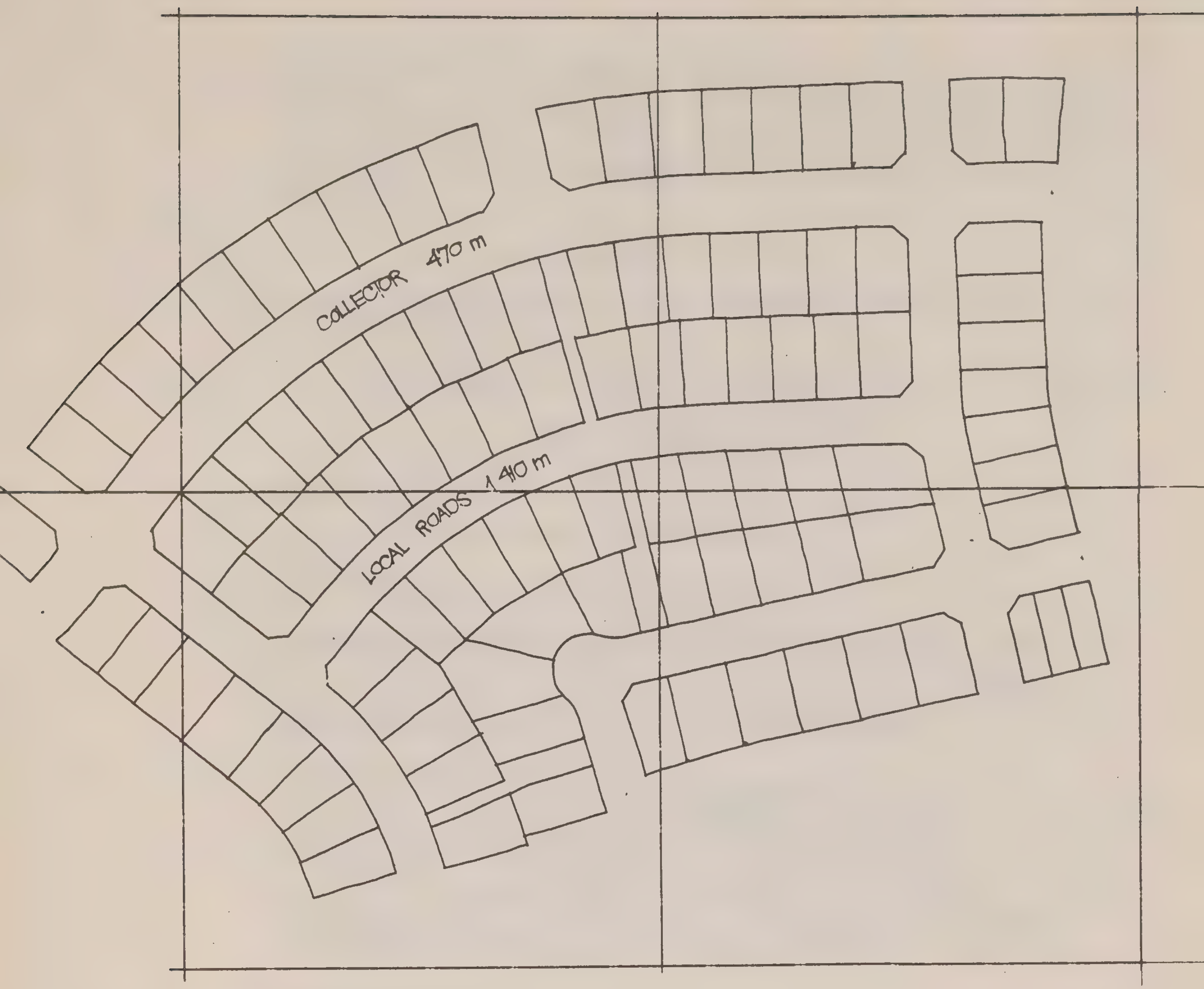


Figure 29

PART OF NEIGHBOURHOOD 1
109 UNITS
TUMBLER RIDGE

1:2500

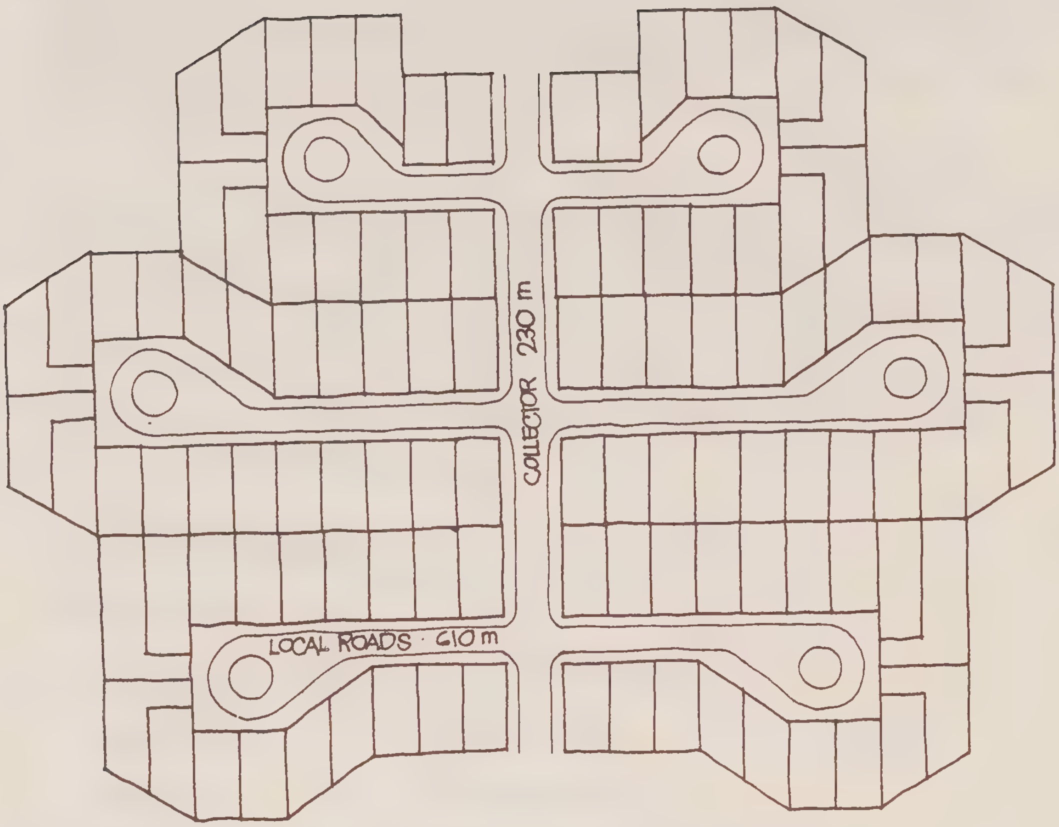


Figure 30

CUL-DE-SAC LAYOUT
108 UNITS
TUMBLER RIDGE

1:2500

* A lineal road cost of $854 / m is assumed for culs-de-sac , even though they are narrower (8.5 m pavement width) than local roads (10 m pavement width). However, the cul-de-sac turnaround consumes additional pavement area, though not additional services length. The figure of $854 / m throughout was felt to balance these two factors.

Unit savings = $8,266.27.

Extrapolating these results across the entire community results in the following benefits:

1,656 units (2,394 - 738 apartments) x savings of $8,266.27 / unit =

<u>$13,688,943</u>

<u>Annualized savings</u>:

Amortized @ 15%, 35 years: $2,064,535

Amortized @ 20%, 35 years: $2,740,437.

Apartment sites were not included in the analysis because they are large areas, and do not affect the road layout significantly. The savings from shorter arterial or collector roads outside neighbourhoods are estimated in section 5.5, <u>Community Layout</u>.

- <u>Site Development Capital Costs</u>

There may be some savings from reduced site preparation and landscaping costs for smaller lots (15 x 30 m = 450 m^2 vs. existing lots of 18 x 36 m = 648 m^2). In the housing industry, these costs are usually allocated on a lot, rather than an area basis, and therefore, are not included as a saving in this analysis. A smaller lot is capable of more intensive landscaping for the same cost than a larger lot.

- <u>Road Operating Costs</u>

<u>Municipal</u>

1,656 units x 9.42 m less road / unit x $10,000 / km municipal operating costs* = 15.6 km x $10,000 = $156,000 annually.

* Municipal operating costs of $10,000 / km are based on an analysis of the 1981 municipal budgets of Fort St. John and Dawson Creek, two comparable nearby communities. They include all costs sensitive to road length, including both the repair and maintenance of roads and underground services, and the variable operating costs of municipal services which must use the roads.

The above savings may have to be reduced slightly, because some municipal officials feel that culs-de-sac incur additional costs in snow removal and street cleaning, due to extra vehicle movements.

Individuals and Businesses

More compact neighbourhoods result in shorter average trip length to the neighbourhood boundary for all home-based trips. This average trip length to the neighbourhood boundary is difficult to estimate accurately, because a complete set of neighbourhood plans and alternatives is not available for comparison. However, some useful approximations can still be made.

For the entire community, the number of significant home-based trips is:

Home to work	1,281,420
Home to Town Centre	3,532,896
Home to School:	too short to be affected, not counted
School to Town Centre:	uses arterial and collector roads
	4,814,316 trips / year.

If the average trip length from home to the closest neighbourhood boundary could be reduced, for example, by 100 m (feasible in terms of the alternatives developed here), this would result in savings of:

481,431 less vehicle km / year @ 8 1/8¢ / km variable costs =	
	39,116.31
Trucks and vans: 10% of car trips @ 12.2¢ / km	5,876.45
	$44,983.76

- District Heating Capital Costs

Part of Neighbourhood 1, 109 units

Collector	8" pipe	470 m @ $480 / m	225,600
Local roads	50% @ 6"	700 m @ $342 / m	239,400
	50% @ 3"	710 m @ $200 / m	144,840
			$609,840

Unit cost = $5,595

(Connection costs not considered)

Cul-de-sac Layout - 108 units

Collector	8" pipe	230 m @ $480/m	110,400
Local Roads	4" pipe	610 m @ $254/m	154,940
	1½" pipe at cul-de-sac ends	180 m @ $166/m	29,880
			295,220

Unit cost = $2,733.52

(Connection cost not considered)

Difference = $2,861.34/unit

Cost differential across the entire community:

1,656 units (less apartments) x savings of $2,861.34/unit =

$4,738,381.50

Annualized savings:

amortized @ 15%, 35 years: $714,631.80

amortized @ 20%, 35 years: $948,593.17

- District Heating Operating Costs

  A shorter piping network will result in lower system heat losses, but these benefits have not been estimated.

5.5 Community Layout

A more compact community is a more efficient community, Shorter roads and services cost less to construct, and over the years, cost less to use and operate.

Because the Community Plan for Tumbler Ridge is still being refined, a direct comparison between a "Plan A" and an alternative "Plan B" is impractical. Therefore this analysis concentrates on illustrating cost savings possible with representative modifications to the existing Tumbler Ridge Community Plan.

Since most of these savings are transportation-based, a general analysis of the travel demands in the Town is appropriate. This is relatively straightforward because Tumbler Ridge is an isolated community with relatively few out-of-town trips (except to the mines) and only a few internal destinations (the Town Centre and schools).

At maturity, the Town will have 1,656 units suitable for couples and family accommodation (1,021 detached, 135 attached, 112 row townhouses, 388 manufactured homes) and 738 apartments suitable for singles and couples. The ratio of mine jobs (1,943) to induced jobs (972) will be 2:1.

The suggested household trip purpose breakdown, based on a number of urban transportation studies, is home-based work: 30%, home-based shopping: 15%, home-based other: 35%, non-home-based other: 20%. It is assumed that apartments will generate 6 vehicle trips per day and all other unit types, 10 vehicle trips per day (Figure 31). Given the small number of destination points in Tumbler Ridge, these trips can be allocated relatively simply, as in Figure 32. This allocation results in the following numbers of trips within the community for each major purpose:

- Home to Mine

Apartments:	1.3 x 738 x 360	345,384
Other:	2.0 x 1,656 x 360	1,192,320
		1,537,704/year

Reduction for car pooling, 1.2 passengers/car:

1,281,420/year

Figure 31

Summary of Trip Generation Rates

ITE Technical Committee 6A-6

Average Weekday Vehicle Trip Ends per Dwelling Unit

	Average	Maximum	Minimum
Single family detached unit	10.0	21.9	4.3
Apartment, General	6.1	12.3	0.5
Apartment, low rise	5.4	5.5	4.7
Apartment, high rise	4.3	6.4	3.1

Figure 32

Car Trip Generation Figures

Purpose	%	Apartments: 6/day	Other Units: 10/day
Work	30	(2) mine 1.3, TC 0.7	(3.0) mine 2.0 TC 1.0
Shopping	15	(1) TC 1.0	(1.5) TC 1.5
Other	35	(2) school 0.5, TC 1.5	(3.5) school 1.5, TC 2.0
Non-home	20	(1) m-TC 0.7, s-TC 0.3	(2.0) m-TC 1.0, s-TC 1.0

- <u>Home to Town Centre</u>

Apartments:	3.2 x 738 x 360	850,176
Other:	4.5 x 1,656 x 360	2,682,720
		3,532,896 / year

- <u>Home to School</u>

Apartments:	0.5 x 738 x 360	132,840
Other:	1.5 x 1,656 x 360	894,240
		1,027,080 / year

- <u>School to Town Centre</u>

Apartments:	0.3 x 738 x 360	79,704
Other:	1.0 x 1,656 x 360	596,160
		675,864 / year

- <u>Mine to Town Centre</u>

Apartments:	0.7 x 738 x 360	185,976
Other:	1.0 x 1,656 x 360	596,160
		782,136
	Reduction for car pooling:	651,780 / year

The variable costs of operating a car (gas, oil, maintenance) which are related to distance are assumed to be 13¢/mile (1981) or 8 1/8¢/km. These present day costs are used without escalation for inflation, fuel prices, and fleet efficiency, because of wide fluctuations in these variables. Costs such as capital amortization and depreciation, which would be incurred in any use of a car, are not included.

It can be seen that the key to achieving major savings in transportation costs for a community like Tumbler Ridge, is to accumulate savings of pennies over millions of trips per year. The overall totals accumulated on this basis can be quite large.

5.51 Cost Analysis

- General Policies

Compact Community Form A: Reduction in average trip distances for each trip purpose, as measured along arterial and collector roads, from neighbourhood boundaries to the destination (for home-based trips) in comparison with the existing Community Plan.

Home to mine	1.0 km	104,115.37
Home to Town Centre	0.5 km	145,523.90
Home to School	0.25 km	20,862.56
School to Town Centre	0.5 km	20,592.73
Mine to Town Centre	0.5 km	26,478.56
		317,573.14
	Add 10% truck trips @ 12.2¢/km:	47,635.97
		$365,209.11 ±

Household savings: $152.50 / year

Compact Community Form B: a more conservative reduction in average trip distances:

Home to mine	0.5 km	52,057.69
Home to Town Centre	0.25 km	71,761.95
Home to School	0.1 km	8,345.03
School to Town Centre	0.25 km	10,296.37
Mine to Town Centre	0.25 km	13,239.28
		155,700.32
	Add 10% truck trips @ 12.2¢/km:	23,355.05
		$179,055.37 ±

Household savings: $74.80 / year

The above costs are representative only of the order-of-magnitude benefits possible with a more compact community plan. Preparation of such a plan might result in modification to, or even improvement to, some of the above figures.

These general measures would be accompanied by significant capital cost reductions for shorter arterial and collector roads, as well as reduced municipal costs.

The benefits of a reduction of 1 km in arterial or collector road length, compared with the existing Community Plan, are significant:

Capital costs, roads and underground services:	$936,000

Annualized savings:

Amortized @ 15%, 35 years:	141,165
Municipal costs	10,500
	$151,665
Amortized @ 20%, 35 years	187,381
Municipal costs	10,500
	$197,881

The benefits in annualized and operating cost savings per km of road, range from $151,600 to $198,000 per year.

If district heating is installed, the savings are even greater:

Capital costs: arterial and collector roads carry main distribution lines, 8 to 14" in diameter, with installed capital costs of $480 to $1,000 / m.

1 km @ $600 / m:	600,000

Annualized savings:

Amortized @ 15%, 35 years:	$90,490.62
Amortized @ 20%, 35 years:	$120,116.00

In addition, there would be lower heat losses from a shorter piping network (not calculated).

The total annual savings per km of road, if district heating is installed:

Low (15% interest rate)

Construction, services, operating:	$151,665
District heating network	90,490
	$242,155

<u>High (20% interest rate)</u>

Construction, services, operating:	197,881
District heating network	120,116
	$317,997, say
	$318,000

- <u>Specific Policies</u>

  For illustration, only one specific policy is assessed: <u>location of apartments close to the Town Centre</u>.

  In general, transportation studies indicate that people will not walk to any destination unless it is within 300 m. Grocery trips and major shopping trips will still be done by car, but a shift in mode from car to walking can be encouraged by sheltered, direct pedestrian paths to the Town Centre from units within 300 m, for trip purposes such as school, recreation, and minor shopping.

  Of the 3.2 trips per day taken between apartments and the Town Centre, possibly one trip per day could be diverted to walking by such measures. Direct road links between apartment areas and the Town Centre might also have to be discouraged, at least to the point where trips by car would take as long as trips by walking.

  Assuming an average trip length by car from apartment to Town Centre of 1 500 m, the value of this modal shift would be:

  738 households x 360 days x 1 trip / day x 1.5 km x .08125 =

  $32,379.75

  Household benefit: $43.88 / year.

  However, it is debatable whether all apartment residents would make use of opportunities to walk, even though it would favourably affect both their health and pocketbooks.

5.6 Conclusions

All of the proposed design patterns: solar access, wind shelter, and compact subdivision and community layout, have economic benefits.

With site planning measures to reduce space heating costs, energy savings vary with the energy conservation quality of the housing. The economic value of such savings varies further with assumptions about the kind of heating system, and fuel costs. Taking the NRC "measures" house as a benchmark for construction quality, site planning measures would have the following values annually, in 1982 dollars:

• Solar Access:	\$24.74 - 44.53 / unit	(natural gas)
	\$33.68 - 60.63 / unit	(electrical)
• Wind Shelter:	\$29.50 - 40.00 / unit	(natural gas - electrical)
• Combined Effects:	\$54.00 - 74.00 / unit	(natural gas)
	\$73.88 - 100.00 / unit	(electrical)

Contribution: 12.7 to 17.3% of heat load.

While these values are not large, it should also be remembered that site planning measures are essentially free, and able to be implemented without cost penalties.

For site planning measures which affect roads and transportation, cost savings do not vary with housing quality, but annual costs are highly sensitive to interest rate assumptions.

Taking the existing neighbourhoods under construction as benchmarks, the potential savings from a compact subdivision layout in 1982 dollars are:

Capital costs			Annualized
Roads and services	\$8,266 / unit	(@ 15%)	1,246.70 / unit
		(@ 20%)	1,654.85 / unit
Operating Costs			
Municipal			94.20 / unit
Individuals and businesses (example only)			18.80 / unit
			\$1,359.70 - \$1,767.85 / unit

Most of the above savings accrue to the community. If district heating is also installed, additional capital cost savings of \$2,861 / unit (\$430.11 (@ 15%) to 572.27 (@ 20%) per unit annualized) may also be realized, resulting in total savings approaching \$1,790 to \$2,340 /

unit annually. However, the introduction of district heating, a cheaper heating source, would tend to reduce slightly, the economic value of solar access and wind shelter.

At the community layout scale, a number of refinements can be made to reduce road capital and transportation costs significantly. The following values are representative only of potential savings from a compact community form (i.e. not based on direct comparisons between two community plans):

- household transportation costs $75 - $150 / year

- every km of arterial or collector road which can be eliminated from the plan will save $151,600 to $189,000 / year to the community. ($242,000 to $318,00 / year with district heating).

From a review of these benefits, its is clear that the highest priority in site planning should be given to measures to create compact subdivision and community layouts, and to reduce the lengths of roads and services. If a district heating system is introduced, the values of these measures would be even greater.

Site planning measures to reduce space heating have relatively less value, but are still desirable if they can be introduced without significant costs (as appears to be the case). The further adaptation of housing units to take full advantage of solar access has not been addressed in this study, but could add greatly to the energy savings already identified.